EFFECT OF MASS MORTALITY OF FERAL HOGS (*SUS SCROFA*): LATERAL AND VERTICAL TRANSPORT OF NUTRIENTS THROUGH SOIL

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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May 2020

Major Subject: Water Management and Hydrologic Science

ABSTRACT

Mass deaths of livestock can present an environmental issue in terms of changes in soil chemistry (Chowdbury et al. 2019) and overall soil/environmental health. The population of some wildlife species have been increasing and are influenced by factors such as water availability, habitat, lack of competition for resources, and lack of predation or disease. One such wildlife species is feral hogs whose population has proven environmentally and economically detrimental to many states in the US. The baiting and killing of these hogs may contribute to a secondary mass mortality event (MME) scenario where decomposition products directly impact soil, plant and insect functions in riparian areas and specifically in areas with soils that are conducive to nutrient transport (such as those sites with higher saturated hydraulic conductivity).

On July 5th, 2016, Mississippi State University researchers simulated an MME to study the effects on an ecosystem in terms of entomology, microbiology, and plant physiology (Lashley et al., 2017; Tomberlin et al. 2017; Wilcox 2017). Three tons of donated feral hog cadavers were placed in experimental plots at 5 different sites in the John Starr Forest in Starkville, Mississippi, USA. Their study served as a site for my research with a major objective of examining the lateral and vertical migration of carbon (C), nitrogen (N) and phosphorus (P) compounds in the cadaver decomposition islands (CDIs) of feral hogs.

This research showed low cadaver mass ($\leq$ 181 kg) decomposition sites did not pose significant threats to the soil environment based on nutrient concentrations. However, as cadaver mass on a site was increased, such as in sites 4 and 5 with masses $\geq$ 363 kg, the potential environmental impacts from high NO_3-N, NH_4-N, and PO_4-P are prevalent. The depth at which these nutrients can move and remain in the soil is also concerning, particularly when

characteristics of the soil are conducive to high transport. For example, soils with a higher saturated hydraulic conductivity will likely see nutrient movement to deeper depths. Scavenging tended to spread nutrients laterally throughout the experimental plots but the concentrations tended to be lower whereas protected cadavers tended to have a high concentration of nutrients at the center of the CDI.

ACKNOWLEDGEMENTS

I would like to thank my advisor and committee co-chair, Dr. Jacqueline Aitkenhead-Peterson, for her continuous encouragement and guidance as well as the strength and motivation she provided me during our arduous time spent in the field together. I would also like to thank Dr. Paul Schwab for his support and valuable insight on this project.

I am appreciative for the funding provided by both of you that allowed for this research and the opportunity to present this research at the Ecological Society of America Meeting in New Orleans, LA. I am forever grateful for both of you consistently believing in me.

Dr. Jake Mowrer and Dr. Jeffrey Tomberlin served on my committee and supported this research through valuable feedback and comments. Special thanks to Dr. Jake Mowrer who brought me into this wonderous world of agricultural research as an undergraduate and believed in my ability to grow in this field. Dr. Jeffrey Tomberlin, without the entomological study that provoked the parent to this project, I would not have had this opportunity.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Professor Paul Schwab and Professor Jacqueline Aitkenhead-Peterson of the Department of Soil and Crop Sciences and Professors Jake Mowrer of the Texas A&M Agrilife Extension and Jeffrey Tomberlin of the Department of Entomology.

Funding Sources

Graduate study was supported by an assistantship from Texas A&M University's Department of Soil & Crop Sciences, specifically through research funding provided by Dr. Paul Schwab and Dr. Jacqueline Aitkenhead-Peterson.

This work was also made possible in part by research funding provided by Mississippi State University researchers, Dr. Marcus Lashley and Dr. Brandon Barton.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

1.1 Mass Mortality Events (MMEs)

Mass mortality events (MMEs) are often defined as rapidly occurring events causing elevated mortality that drastically reduce population abundance (Reed, O'Grady, Ballou, Frankham 2003; Fey et al., 2015). Mass mortality events may be caused by physical (e.g., lightning strikes, fire outbreaks), chemical (e.g., pollutants, hypoxia, toxins), or biological processes (e.g., disease or phenological mismatch with food source) (Lashley, Jordan, Tomberlin, Barton 2017). Recent shifts have been observed in the occurrence, cause, and magnitude in animal MMEs (Fey et al., 2015). Mass mortality events tend to be associated with a rise in disease, biotoxicity, and other events caused by multiple stressors; however it is not clear whether MMEs are truly increasing or that the increase observed is due to elevated reporting (Fey et al., 2015). In 2015, an MME of 200,000 saiga antelopes over a three-week period in central Kazakhstan received global attention (Kock et al. 2018). Cause of death of these saiga antelope was postulated to be hemorrhagic septicemia (Kock et al., 2018). A separate incident involved virus-induced epizootic hemorrhagic disease which killed 500-700 white tailed deer in New Jersey, USA in 1955 (Shope, MacNamara, Mangold 1960). Unfortunately, many MMEs, though reported in local news at the time of discovery, are not researched by the scientific community with results published.

Domestic livestock also have suffered MMEs, termed disease outbreaks, linked to epizootic hemorrhagic disease (EHD) and blue tongue virus (BTV) (Stevens, McCluskey, King, O'Hearn, Mayr 2015).

This thesis follows the format of Journal of Ecology

EHD has been reported in cattle (129 herds), captive white-tailed deer (65 herds), bison (8 herds), yak (6 herds), elk (1 herd) and sheep (1 flock) (Stevens et al., 2015). The average mortality was 6% in cattle and bison herds and 42% in white tailed deer herds (Stevens et al., 2015). One of the largest cases for domestic livestock was in the United Kingdom in 2001 when foot and mouth disease was rampant. The disease did not induce mass mortality *per se*, but approximately 6-10 million infected sheep and cattle were culled to stop the spread of disease (Mort, Convery, Bailey, Baxter 2004). The time between slaughter and removal of the carcasses took weeks in some cases with little concern on the environmental impact of decomposing animals (Mort et al., 2004).

1.2 Decomposition of Vertebrate Mammals

Despite the increased frequency of mammals dying for reasons other than predation (Fey et al., 2015), the nutrient loading to soil resulting from the decomposition of dead mammals has been relatively underrepresented in literature. Most vertebrate mammal decomposition studies have been used for the field of forensics with *Sus scrofa domesticus* typically used as an analogue for humans (Anderson, Meyer, Carter 2013; Perrault & Forbes, 2016; Szelecz, Koenig, Seppey, Le Bayon, Mitchell 2018). Carter, Yellowlees, and Tibbett (2007) suggested six general stages of cadaver decomposition (fresh, bloated, active decay, advance decay, dry remains) which is coupled with autolysis (enzyme breakdown of cells) and putrefaction (protein breakdown by bacteria).

Of the six proposed stages, the two most important to the study of decomposition products in soil are active decay and advanced decay (Fig. 1). Active decay is the period of greatest loss of mass and is characterized by insect, fungi, and bacterial prevalence (Carter et al., 2007). During

active decay, decomposition fluids are purged from a carcass into the soil environment creating a cadaver decomposition island (CDI) which is a highly concentrated island of fertility (Carter et al., 2007).

Figure 1. Decomposition stages from left to right: fresh, bloat, active decay, advanced decay, dry remains/skeletal remains. Author: Hbreton19 [permission is granted by the author under the Creative Commons Attribution-Share Alike 3.0 Unported license to use this photograph for distribution, modification, or copying https://commons.wikimedia.org/wiki/File:Decomposition_stages.jpg]

The CDI turns anaerobic due to the purge of decomposition products into the soil and initially has high concentrations of organic carbon and nitrogen as well as nutrients such as ammonium-nitrogen (NH_4-N) , orthophosphate-phosphorus (PO_4-P). As advanced decay of skeletal remains occurs, potassium, calcium and magnesium concentrations in the soil increase and may remain in the soil for months to years (Towne, 2000; Brathen, Danell, Berteaux 2002; Glanville, 2006; Aitkenhead-Peterson, Owings, Alexander, Larison, Bytheway 2012; Aitkenhead-Peterson, Alexander, Byetheway, Carter, Westcott 2015; Fancher et al., 2017). Initially high concentrations of NH_4-N and an anaerobic CDI have been observed to remain for over 1 year (Aitkenhead-Peterson et al. 2015). Nitrate (NO_3) concentrations in the CDI are lower than in control soils because both NO_3^- and sulfate (SO_4^{2-}) are used by bacteria in this anaerobic environment. After about 1 year, as the CDI becomes aerated through plant growth and wildlife foraging, and NO_3-N peaks with a concomitant decrease in NH_4-N. Based on prior research at the Forensic Anthropology Research Facility of Texas State University (San Marcos, Texas), leachate from human cadavers is readily transported down the soil profile (Fancher et al., 2017) and does not remain in the top 5 cm. General decomposition timelines for surface-placed cadavers show the active stage decomposition occurring within 6 to 18 days post-mortem when weather factors are permitting (Aitkenhead-Peterson et al., 2015; Fancher et al., 2017).

While many studies have examined decomposition products in the soil beneath surface placed cadavers, some studies have examined decomposition products from buried cadavers (Glanville, 2006; Kwon et al., 2017). Early investigations into the effects of livestock mortality on groundwater quality were considered for normally occurring mortalities on a farm. In one experiment by Glanville (2006), two burial trenches were constructed to 1.2 m deep and 2.4 m apart and were filled with six swine carcasses each. Each trench was studied in well-drained,

moderately permeable soil. Swine decomposition leachate samples in one trench lined with PVC sheeting and 100mm gravel (for pan lysimeter installation) captured NH_4-N, chloride (Cl^-), and NO_3-N. Monitoring wells surrounded the other trench and were sampled for biological oxygen demand (BOD), NH_4-N, total dissolved solids (TDS), and chloride reaching 1-2 m downgradient.

Unfortunately, the Glanville (2006) study was exposed to rainwater during the duration of the experiment and so does not represent a pure leachate example. Despite this, Glanville (2006) was able to conclude that localized contamination could persist for longer than a decade in wet soil with a seasonally high water table and low groundwater flow velocity but would be detrimental to water quality in areas with high water tables and high groundwater flow velocities. Kwon et al. (2017) examined groundwater monitoring wells adjacent to a swine burial site and reported high (approximately 5780 µS/cm) electrical conductivity and high major ion concentrations. They found, however, rapid dilution of decomposition products by ambient groundwater. Other researchers in Saskatoon, Saskatchewan, Canada analyzed pure livestock mortality leachate in five constructed burial pits (Pratt & Fonstad, 2017a). One pit was selected to examine leachate from 5900 kg of swine carcasses. The swine pit was lined with polyethylene and was sealed with another layer of polyethylene so that a pure leachate sample could be obtained via collection system (Fig. 2). Two acrylonitrile butadiene styrene pipes were also installed for gas transfer (Fig. 3). Samples were collected at two weeks post-placement and then monthly from August-November 2005, again in May and October of 2006, and finally, September of 2007. The chemical composition of swine leachate showed significant threats to groundwater quality with high concentrations of total alkalinity (39,700 mg/L), sodium (1,700 mg/L), sulfate (3,900 mg/L), phosphorus (1,515 mg/L) and organic carbon (65,000 mg/L).

Figure 2. Lined Burial Pit. Reprinted with permission from Pratt & Fonstad (2017a).

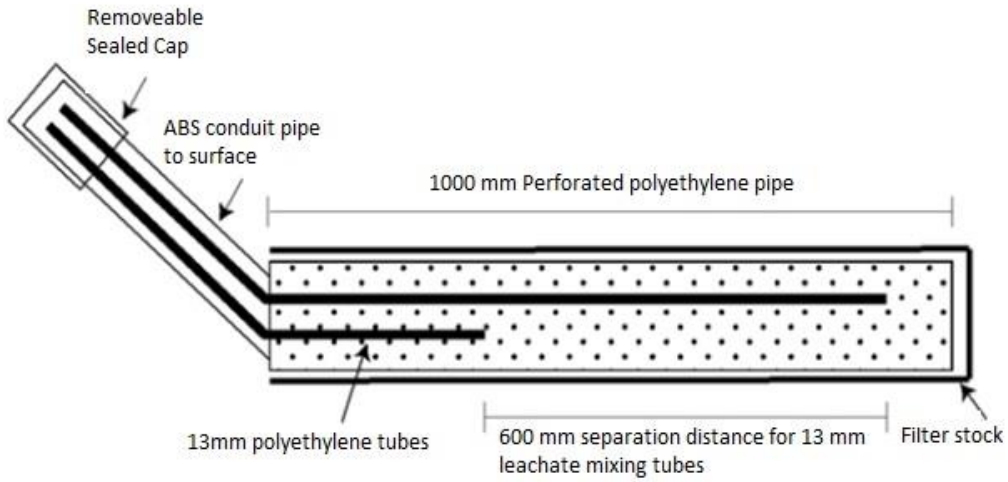

Figure 3. Cross-sectional view of burial pit with ABS vents. Reprinted with permission from Pratt & Fonstad (2017a).

A mass mortality event simulation modeled contamination of 15,000 mg L^{-1} NH_4-N through a low, moderate, and permeable soil with no attenuation or adsorption using a graphical interface program called CTRAN (Pratt & Fonstad, 2017b). Nutrient transport through soil was evaluated within a 1-D column for the three soil permeability's with 10,000 mg L^{-1} NH_4^-N input.

The high input of NH_4-N was based on high concentrations (10,400-14,100 mg L^{-1}) observed in livestock leachate (Pratt, 2009). The CTRAN results for a low permeable soil showed minimal transport after 10 years, after 100 years the contaminant plume had only reached 4 meters with a reduction in NH4-N concentration to 500 mg L^{-1}. The moderately permeable soil depicted 10% of the initial concentration (i.e. 1,000 mg L-1) and reached a depth of 10 m in 50 years. The permeable soil simulation demonstrated 10% of initial concentration and reached 10 m in 10 years.

To evaluate the leachate nutrient risks on the groundwater environment based on ion activity and ionic strength, speciation, and saturation indices, Pratt & Fonstad (2017b) used a geochemical model called PHREEQC (ver. 3.3.9) which showed groundwater infiltration concentrations exceeded drinking water or aquatic life standards for bicarbonate (by 30-50 times), calcium (by 65 times), magnesium (by 17 times), and chloride (by 6 times).

1.3 Expansion of Feral Hogs in the USA

The population of some wildlife species has been increasing and influencing factors such as water availability, habitat, lack of competition for resources, and lack of predation or disease. Populations of feral hogs (*Sus scrofa*) are widespread in the southern states of USA (Fig. 4). Their population is reported at 6 million and rapidly expanding due to their reaching reproductive maturity around six months old and giving birth to up to twelve young per litter under favorable conditions (Taylor, 2017). These uncontrolled feral hog populations also pose a threat to the biosecurity of modern livestock management facilities due to their potential as a vector of foot and mouth disease (this potential impact is modeled in McReynolds, Sanderson, Reeves, Hill 2014). McClure et al. (2015) suggested that climate may restrict movement of feral hogs to the far northern states but predicted an expansion to most states in the USA.

Feral hogs have the largest population in Texas, estimated at 2.6 million (Mayer & Brisbin, 2009). These populations in Texas alone result in $52 million dollars of agricultural damage through rooting and trampling behaviors each year. In addition to the damage caused to agriculture by feral hogs, several reports link feral hogs with damage to ecosystems in general. For example, alterations to carbon dynamics (Persico, Sharp, Angelini 2017) and decline in salamanders (Jones et al., 2017). Increased soil NO_3-N and declines in seedling species richness (Krull, Choquenot, Burns, Stanley 2013) have been postulated to be caused by feral hogs.

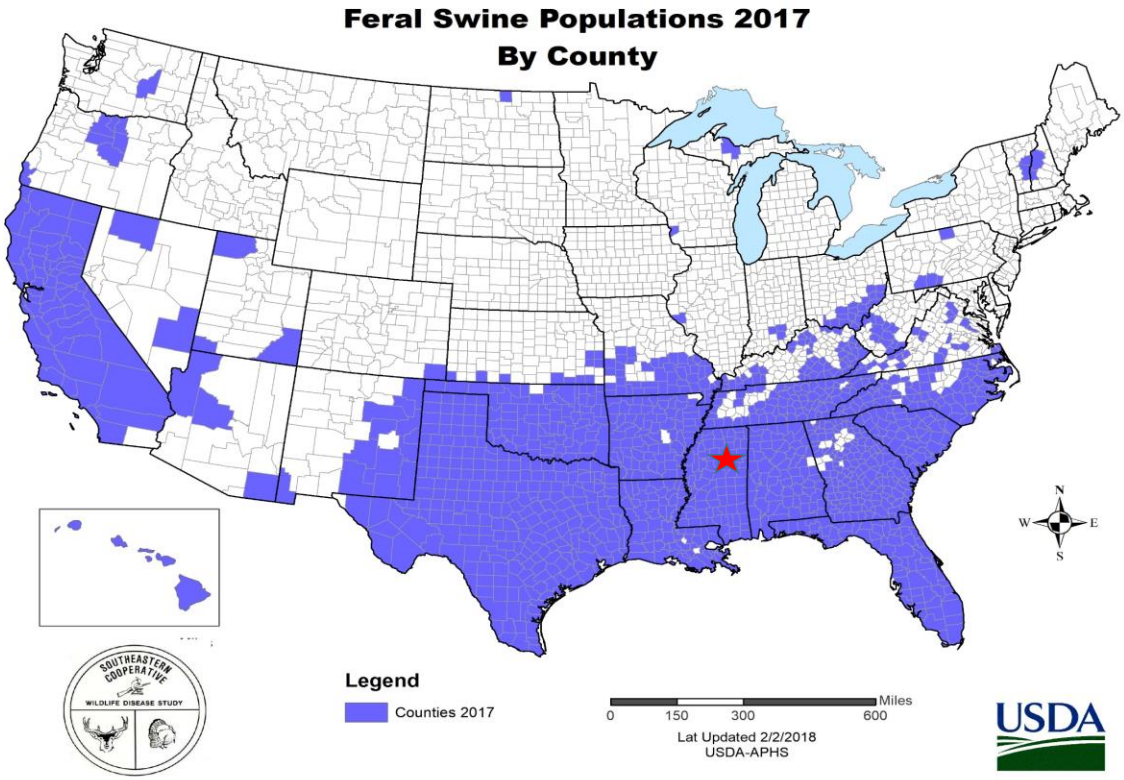

Figure 4. Population of feral hogs in the USA. Red star indicates research sites. Adapted from USDA Aphis (https://www.aphis.usda.gov/wildlife_damage/feral_swine/images/2017-feral-swine-distribution-map-county.jpg)

Multiple efforts to control feral hog populations occur on a global scale and include trapping, shooting, poisoning and use of Judas hogs (Massei, Roy, Bunting 2011). A Judas hog is fitted with a radio tracking collar and sent out so that it can be tracked as it searches for a a group of hogs to join after its own family has been eradicated. Non-lethal methods of control have included fertility control, fencing, repellents, diversionary feeding and translocation (Massei et al., 2011). In terms of poisoned baits, micro-encapsulated sodium nitrite (MESN), sodium fluoroacetate (also known as 1080), yellow phosphorus (CSSP), and warfarin have been used. Snow et al. (2018) reported a potential for secondary poisoning for non-target species when MESN was used in Texas. *The biggest issue with use of poison baits may be the occurrence of mass mortality events and the effect these may have on environmental health*. Therefore, it is useful to monitor the changes in whole ecosystem function resulting from both naturally induced and human induced MMEs.

1.4 Objectives and Hypotheses

On July 5th, 2016, Mississippi State University (MSU) researchers simulated a MME to study the effects on an ecosystem in terms of entomology, microbiology, and plant physiology (Lashley et al., 2017; Tomberlin, Barton, Lashley, Jordan 2017; Wilcox, 2017). Three tons of donated feral hog cadavers were placed in experimental plots at 5 different sites in the John Starr Forest in Starkville, Mississippi, USA (Fig. 5).

Figure 5. Map of Mississippi, USA with Starkville highlighted. Red star indicates research sites. Adapted from Greater Development Starkville Partnership (https://www.starkville.org/economic/maps/)

The research in this thesis builds on the MSU experiment with a major objective to examine the lateral and vertical migration of water extractable soil organic carbon (C as non-purgeable dissolved organic carbon) and nutrients, nitrogen (N as NO_3-N, NH_4-N and dissolved organic nitrogen DON) and phosphorus (P as PO_4-P).

Objectives

1. Examine the migration of water extractable carbon (C), nitrogen (N), phosphorus (P) compounds both laterally and vertically in the CDI; comparing hog plots to control plots

2. Determine water extractable soil nutrients from hog plots exposed to scavengers compared to hog plots protected from scavengers
3. Examine the decomposition products (Hog soil minus control soil) to determine the effect of mass on individual water extractable nutrients

Hypotheses

H_{O1}: There is no significant difference between C, N, P concentrations in the CDI of hog plots versus control plots

H_1: There is a significant increase in all nutrient concentrations in the CDI of hog plots compared to control plots due to the purging of nutrients from the cadavers

H_{O2} There will be no significant difference in nutrient concentrations when comparing hog decomposition plots fenced or open to scavengers

H_2 There will be significantly higher water extractable nutrients in plots protected from scavengers because scavengers will disperse carrion resulting in a wider spread but lower concentration

H_{O3} There will be no significant effect of hog mass or hog treatment on water extractable nutrients analyzed

H_3 Hog plots will have a defined CDI such that nutrients will be higher beneath the center plot positions and show translocation down the soil profile

CHAPTER II

WET CHEMICAL ANALYSES OF DECOMPOSITION PRODUCTS IN SOIL

2.1 INTRODUCTION

Electrical conductivity (EC) and pH are useful indicators of soil health and are greatly influenced by environmental factors such as climate, biota, geology, and human impacts (Karlen, Andrews, Wienhold, Zobeck 2008). In general, EC is used to determine the amount of dissolved salts in an aqueous solution which relates to its ability to conduct electrical current. In this study, EC will serve as an indicator for nutrient availability to plants with low EC reflecting nutrient poor soil that is unstable and disperses readily, and high EC reflecting poor plant growth (Karlen et al., 2008). pH is an important factor in groundwater contamination as it affects the degree of dissociation of weak acids and bases, the toxicity and persistence of certain compounds, and dictates the growth and activity of microorganisms (Alhajjar, Chesters, Harkin 1990). pH is used in combination with EC to further understand the productivity of soil as an environment conducive or unfavorable to plant growth and microorganism presence (Karlen et al., 2008).

Nutrient compounds from cadaver decomposition have been analyzed via aqueous extracts since the early 90s to determine time since death of human cadavers (Vass, Bass, Wolt, Foss, Ammons 1992) and the impact of existing poultry cadaver disposal pits on ground-water quality (Ritter & Chirnside, 1995). In recent years, the potential for water-soluble nutrient migration into freshwater and groundwater sources from grave sites (Aitkenhead-Peterson et al., 2012) and evaluations of specific nutrient compounds in cadaver decomposition leachate of varying livestock species (Pratt & Fonstad, 2017a) have shown NO_3-N, NH_4-N, and PO_4-P to be primary contaminant concerns.

Nitrogen (N) is a primary macronutrient essential for plant growth; thus, N application in the form of urea fertilizer ($CO(NH_2)_2$) is important to agricultural practices. Urease enzymes break down urea to ammonia (NH_3-N), which exists in pH-dependent equilibrium with NH_4-N when dissolved in water. Nitrifier bacteria use NH_4-N for energy and produce NO_3-N, in a process called nitrification. Leaching (loss of N through soil profile from solubility of anionic nitrate) can cause surface and ground water contamination (Di & Cameron, 2004).

Dissolved organic carbon (DOC) is an important factor in microorganism activity and soil health, and can influence the mobility of nutrients, metals, and pollutants. It also works in conjunction with dissolved organic nitrogen (DON) cycling in the environment (Aitkenhead-Peterson et al., 2003; Berg, Shotbolt, Ashmore 2012). A DOC and DON extraction method for soil samples has not been standardized (Jones et al., 2006), however, based on achieving a maximum extraction of DOC at a longer shaking time, the practice of shaking a 1:10 (soil: water) for 20-22 hours has been adopted (Aitkenhead-Peterson et al. 2012; Aitkenhead-Peterson et al. 2015; Fancher et al., 2017). The presence of DOC has been found extensively in grave soils (Aitkenhead-Peterson, 2012; Fancher et al., 2017; Macdonald et al., 2013). For example, Aitkenhead-Peterson et al. (2012) reported concentrations of DOC as high as 3836 μg g^{-1} soil in a 288 d old CDI compared to 150 μg g^{-1} in control soil. In Fancher et al., (2017), DOC concentrations were reported higher than 10,000 μg g^{-1} in a CDI of approximately 150 d with maximum DOC in control at 300 μg g^{-1}. While concentrations of DOC appear to diminish at the 0-5 cm depth over time, it appears that this is likely due to migration of DOC to deeper depths in the soil profile (Fancher et al., 2017).

Specific ultraviolet absorbance ($SUVA_{254}$) is used to examine the aromaticity of dissolved organic matter at a wavelength of 254 nm. This aromaticity determines whether DOC in solution

is labile (readily available as an energy source and biodegradable) or recalcitrant (resistant to decomposition) (Rovira & Vallejo, 2002). Ecologically, the biodegradability of soluble organic matter is an important factor in stabilization and destabilization of soil organic matter (Marschner & Kalbitz 2003). The parameter of $SUVA_{254}$ is highly correlated with aromatic compounds in aqueous solutions so can be used as a proxy for aromaticity (Weishaar et al. 2003). However, decreasing specific UV absorbance can also indicate increasing portions of microbial compounds such as sugars and low molecular weight acids, and decreasing portions of lignin compounds (Kalbitz et al. 2004). $SUVA_{254}$ analysis is not commonly used in grave soil research, rather, it is more often used to determine biodegradability of DOC in soil solutions for wetlands, grasslands, and forests (Peacock et al., 2014; Kalbitz et al., 2003). Biodegradability of DOC in soil solutions has been reported as ranging from 16-68% (Zsolnay and Steindl 1991; Qualls & Haines 1992; Adreasson, Bergkvist, Baath 2009; McDowell et al. 2006). In forests with pine and hardwood trees, the range was found to be 17-45% in soil solution (Yano et al., 1998).

Preliminary studies on the biodegradability of water extractable DOC obtained from cadaver decomposition islands observed that 85% of the variance in $SUVA_{254}$ was explained by biodegradable DOC ($R^2 = 0.85$; $p = 0.008$) The biodegradability of DOC is a natural, ecological phenomenon yet the biodegradability of DOC in soil CDIs was much lower than expected (30-48%) compared to DOC in a forest control soil (48%); similarly the $SUVA_{254}$ ranged from 2.7 to 4.7 L mg C^{-1} m^{-1} in CDIs compared to 2.3 L mg C^{-1} m^{-1} in a forest control soil (*Aitkenhead-Peterson unpublished data*).

2.2 MATERIALS AND METHODS

2.2.1 Site Description

This study was conducted at the John Starr Forest in Starkville, Mississippi, USA. The forest is owned by Mississippi State University and managed by the Forest and Wildlife Research Center. Dominant vegetation in forest were post oak (*Quercus stellata*), pine (*Pinus* spp.), willow oak (*Quercus phellos* L.), red oak (*Quercus falcata*), and sweet gum (*Liquidambar styraciflua*) (Schauwecker et al., 2011). Average annual temperature at the site is 16.9° C and annual precipitation is 1402 mm. Because of the large area (33.36 km^2), several soil orders were observed and included Ultisols, Alfisols, Inceptisols, and Entisols (Table 2). Unfortunately, the experimental design was initiated in 2016 without consideration of soil series or soil orders.

Figure 6. Location of the plots for Site 1 in the John Starr Forest, Starkville, Mississippi. C is control, FH is fenced hog and OH is open hog. LoA is 90% soil series Longview. Modified from Soil Web (https://casoilresource.lawr.ucdavis.edu)

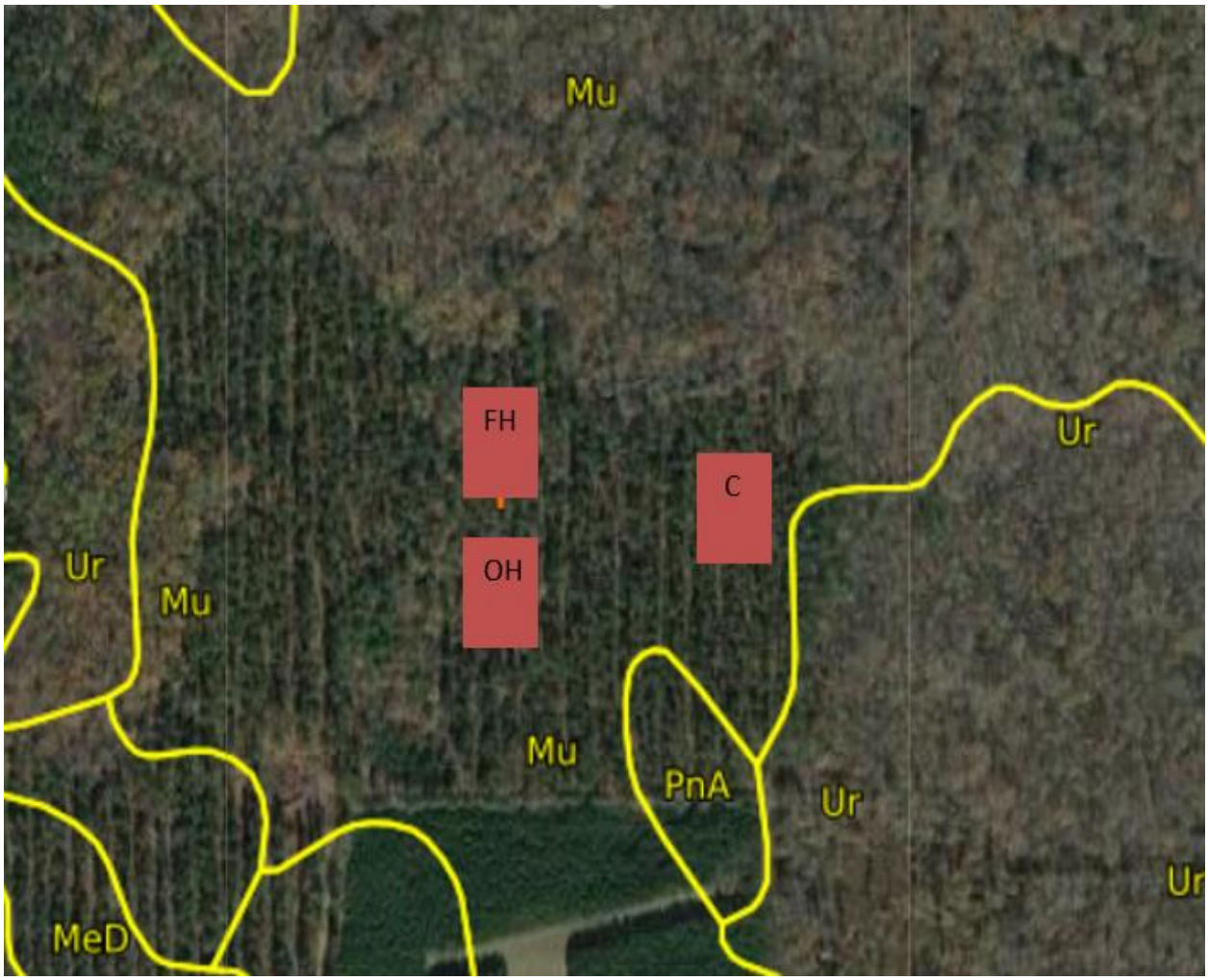

Figure 7. Location of the plots for Site 2 in the John Starr Forest, Starkville, Mississippi. C is control, FH is fenced hog and OH is open hog. Mu is 90% soil series Mathiston. Modified from Soil Web (https://casoilresource.lawr.ucdavis.edu)

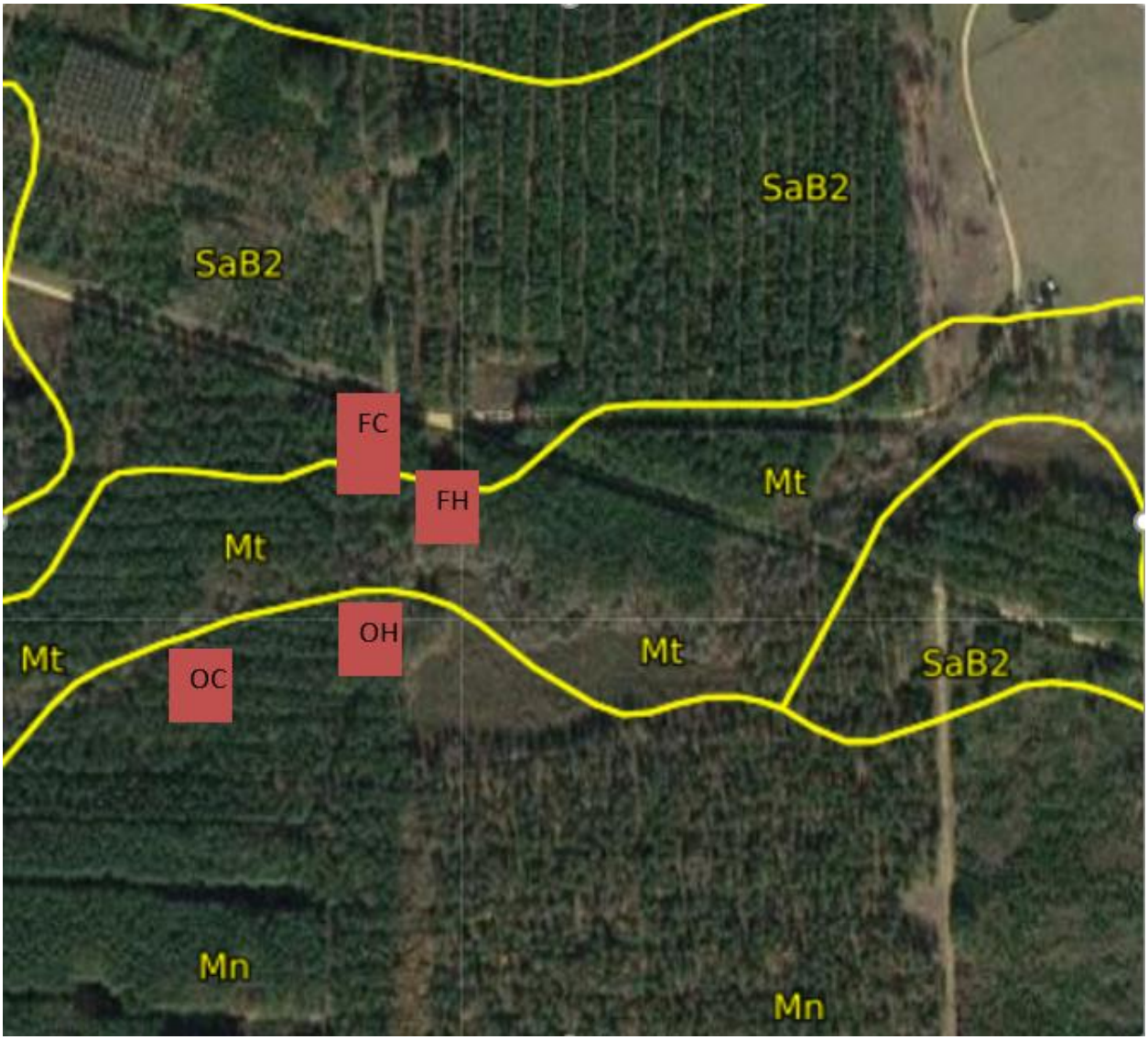

Figure 8. Location of the plots for Site 3 in the John Starr Forest, Starkville, Mississippi. OC is open control, FC is fenced control, FH is fenced hog and OH is open hog. Mt is 90% Mathiston soil series and Mn is 95% Mantachie soil series. Modified from Soil Web (https://casoilresource.lawr.ucdavis.edu)

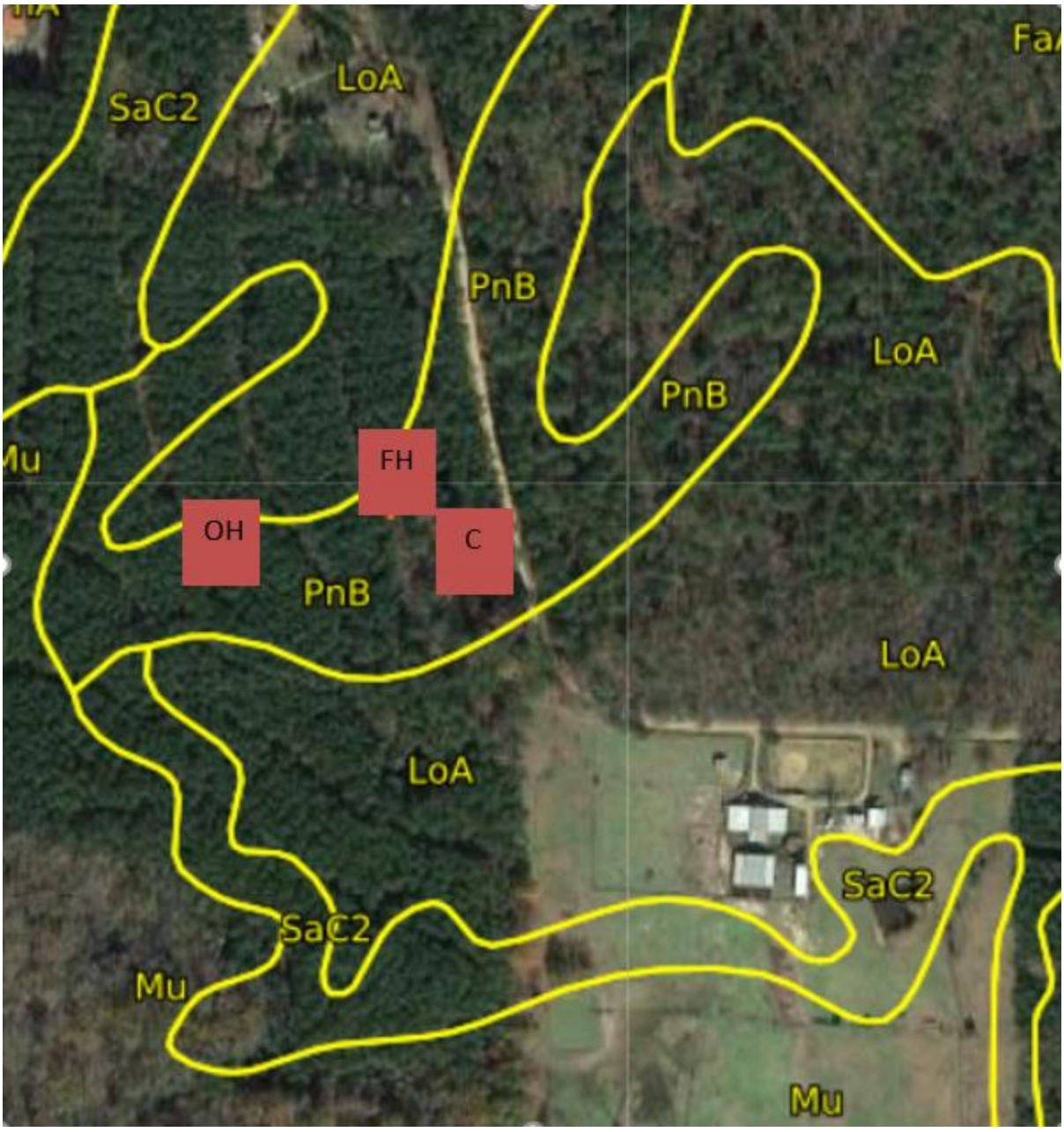

Figure 9. Location of the plots for Site 4 in the John Starr Forest, Starkville, Mississippi. C is control, FH is fenced hog and OH is open hog. PnB is 95% Prentiss soil series. Modified from Soil Web (https://casoilresource.lawr.ucdavis.edu)

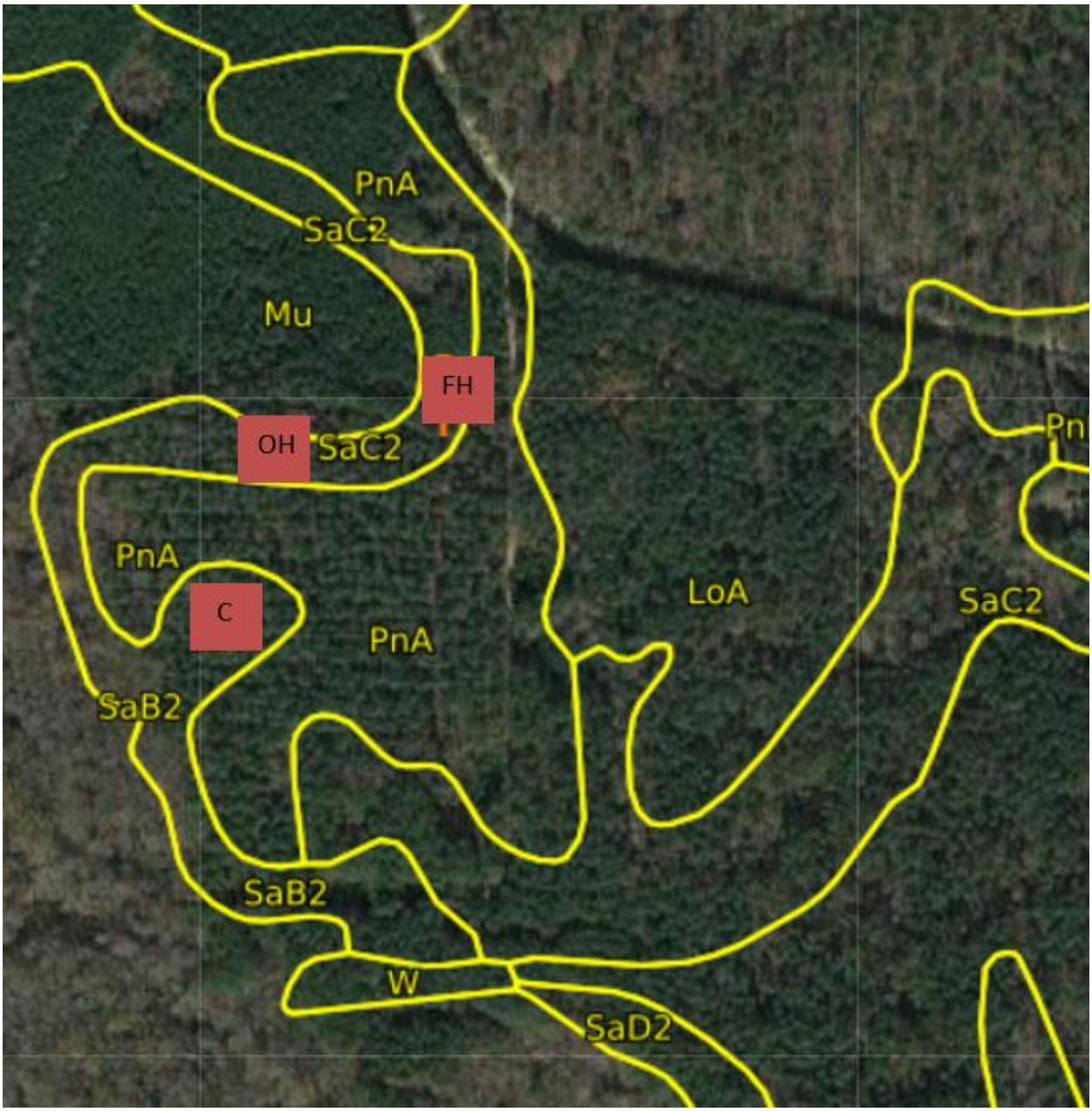

Figure 10. Location of the plots for Site 5 in the John Starr Forest, Starkville, Mississippi. C is control, FH is fenced hog and OH is open hog. SaC2 is 90% Savannah and 4% Prentiss soil series and SaB2 is 90% Savannah and 3% Prentiss soil series. Plot OH falls on the line between the two soil groups. Modified from Soil Web (https://casoilresource.lawr.ucdavis.edu)

2.2.2 Experimental Design

There are five separate decomposition sites in the John Starr Forest (Figures 6 – 10). Each site contains 6 plots, 100 m apart from each other, in a 3 x 2 factorial design, crossing "input" (control, NPK fertilizer equivalent, or feral hog carcass) and vertebrate access (open plot versus fenced plot to exclude scavengers such as coyotes, vultures, or other large necrophagous predators). The NPK fertilizer equivalent plots were not used for this study. While there is no true replication for these plots such as 2 - 3 plots having the same treatment at each site; replication was achieved by sampling each treatment plot (Control, Fenced Hog, Open Hog) at each site five times at separate 3 depth intervals (Figure 11) The distinction between the five sites is cadaver biomass; feral hog carcasses weighing 25, 59, 181, 363, and 726 kg.

2.2.3 Soil Sampling

Soil sampling at each of the five sites occurred in January 2018. Two sites had control plots whose soil series and order did not match up with their corresponding hog plots (Sites 3 and 4) so new control soils were collected for these sites in early May 2018 and the control soils collected for these sites in January 2018 were discarded prior to analyses. Characteristics of each site are dissimilar based on their soil texture (Table 1).

Table 1. Characteristics of the soils at each of the study sites. Ksat is saturated hydraulic conductivity. This data was assigned using the Soil Web application (https://casoilresource.lawr.ucdavis.edu) based on the site coordinates and soil series.

Site	Map Code	Series	Order	Hog	Depth	Sand	Silt	Clay	Bulk Density
				kg	cm		%		g/cm^3
Site 1	LoA	Longview	Alfisol	25	0-10	14.2	71.8	14	1.37
					10-66	9.5	68	22.5	1.62
Site 2	Mu	Mathiston	Entisol	59	0-15	11	71	18	1.49
					15-36	11	67	22	1.48
Site 3	Mt	Mathiston	Entisol	181	0-15	11	71	18	1.49
					15-36	11	67	22	1.48
	Mn	Mantachie	Inceptisol		0-20	40	45	15	1.52
					20-51	38	36	26	1.63
Site 4	PnB	Prentiss	Ultisol	363	0-13	32.3	56.2	11.5	1.51
					13-71	30	55	15	1.65
Site 5	SaC2/SaB2	Savannah	Ultisol	726	0-15	63.9	26.6	9.5	1.62
					15-56	55	20	25	1.67

Coordinates for each site and plot were recorded so that soil series and soil order could be tracked using the SoilWeb application. A transect was measured and flagged from north to south with the center point as the center of the hog decomposition. Distance to northern and southern points was 3 m and a mid-point of 1.5 m was also flagged for sampling (Fig. 6). Sureshot soil corers (2 cm diameter) were used to collect one core at each flag. Each core was divided into 0-10, 10-20, and 20-30 cm depth increments and placed in a labeled zip-lock sample bag. For each plot, 5 cores of 3 depth samples were retrieved (n = 15). Replicates were considered as 5 samples at 0-10 cm (5 replicates), 5 samples at 10-20 cm (5 replicates) and 5 samples at 20-30 cm (5 replicates) for each site sampled. Zip-lock bags were left open over-night to help air-dry and mitigate change in soil chemistry due to anaerobic conditions.

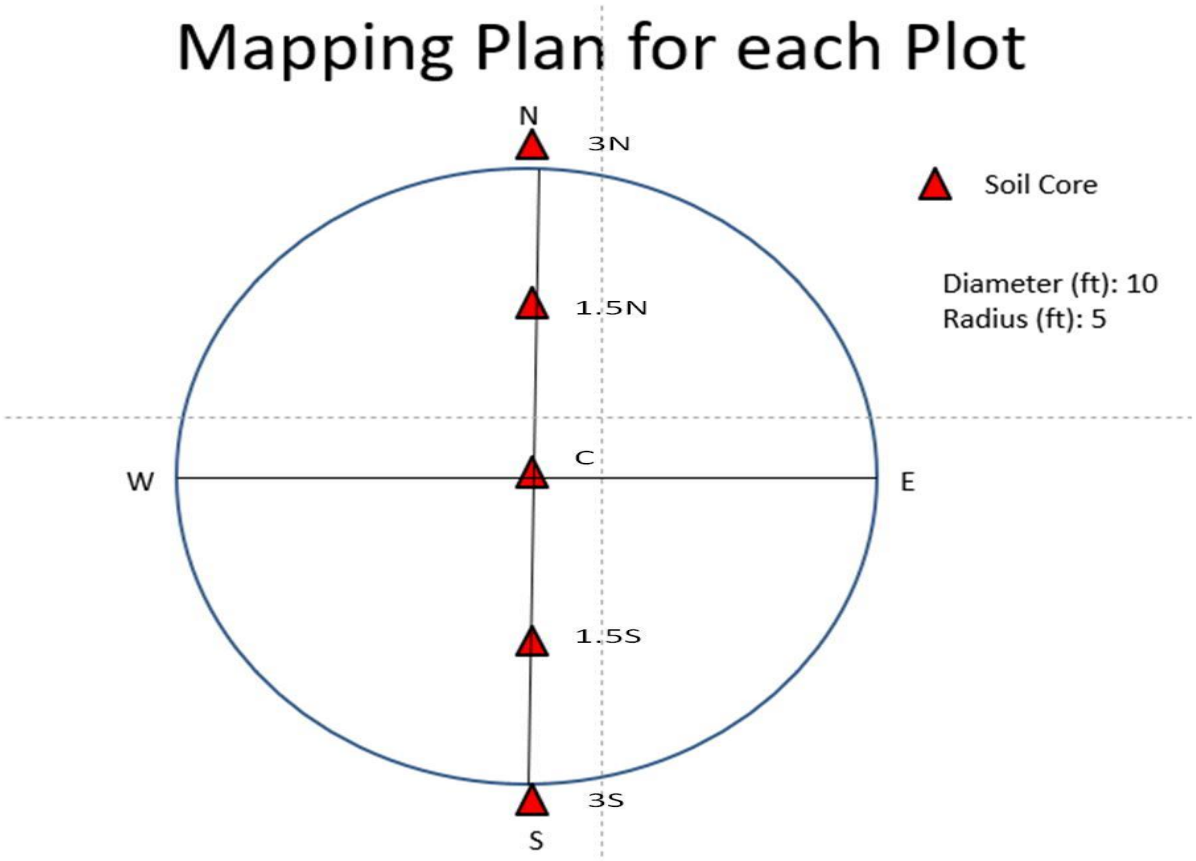

Figure 11. Transect used for each plot in the John Starr Forest of Starkville, MS, USA. Soil cores to a depth of 30 cm were taken along each point and split into 10 cm increments. This experimental design allowed for 5 replicate samples each treatment for each 10 cm depth increment. 3N to 3S nomenclature is used to show sample position in the CDI.

To confirm that control plots were the same soil series as hog plots at each of the sites we used A Delta Premium X-Ray Fluorescence analyzer (XRF) (Olympus Corporation of the Americas, Center Valley, PA, USA) on the 0-10 cm depth of the North and South (3N and 3S sampling positions; Figure 11) at each plot. This data was then analyzed using cluster analyses (Wards Method with squared Euclidean distance) to confirm that each site had the same soil series for each of the plots sampled. This method was used in Fancher et al. 2017 to distinguish

between two soil series and confirm that the sampled plots within each soil series were compatible with their respective control soils. While the same cluster analysis was performed on XRF data, the method of acquiring the data was different. In the Fancher et al. (2017) study the XRF instrument was used on air-dried 2 mm sieved soil whereas in my study, soils were pre-processed further prior to analyses using XRD.

The Olympus handheld XRF analyzer provides fast, nondestructive elemental analysis from parts per million to 100% and is configured with a 40kV miniature X-Ray tube, advanced Silicon Drift Detector, specialized filters, and a multi-beam optimization. Excitation source is a 4W Ag, Rh, Au, or Ta anode (per application) X-Ray tube. The analytical range for alloy and mining is: Mg and up for Rh/Ag and Al and up for Ta/Au; Soil: P and higher. Before use, a calibration check was run using a 316 Stainless Steel Calibration Check Reference Coin (Olympus Corporation) and did not need be run again for the duration of sampling. Each sample was scanned twice: once in "Soil Mode" and once in "Geochem Mode," as each mode picks up different elements. A San Joaquin Soil (2709a) Standard Reference Material (http://www.nist.gov/srm) was scanned to run QAQC every 20th sample for instrument precision.

The air-dried 2 mm sieved soils were further sieved to a 0.5 mm particle size. XRF Sample Cups (Chemplex Industries Inc., Palm City, FL, USA) with dimensions 30.7 mm O.D. x 22.9 mm were ½ to ¾ filled with soil and sealed with Chemplex Spectro Certified Thin Prolene-Film. Each sample cup was placed inside a table-top Delta X-Ray Fluorescence (XRF) Workstation (Olympus Corporation) which provides a safe closed-beam test chamber for analysis and regulatory compliance for detectable radiation below the limit for an uncontrolled area.

Site 1 had a Longview soil series (Alfisol) for its hog and control plots (Table 1) and they appear to be centered in that specific soil series (Figure 6). However, cluster analyses showed that the fenced hog (N), fenced hog (S) and control (S) were in a separate cluster to the open hog (N), control (N) and open hog (S) separated by a large squared Euclidean distance suggesting the control and hog plots were significantly different (Figure 12). Site 2 had Mathiston soil series (Entisol) for its hog and control plots (Table 1) and the plots appear to be centered in that specific soil series (Figure 7). All hog and control soils for this site clustered together with a low squared Euclidean distance suggesting that they were not significantly different (Figure 12). Site 3 had two soil series, Mathiston (Entisol) and Mantachie (Inceptisol) (Table 1). Because of their spatial positioning it was likely that they did not fall in a true Mathiston or Mantachie soil series (Figure 8). Cluster analyses showed the Mathiston soils cluster well with a low Euclidean distance suggesting that the control plot for the fenced hog plot were not significantly different (Figure 12). The Mantachie soils did not cluster well; the open hog (N) and open hog (S) had a very high squared Euclidean distance from the control (N+S) suggesting that the control plot for the open hog plots were significantly different (Figure 12). Site 4 had one soil series a Prentiss (Ultisol) and the plots appeared to fall on this soil series (Figure 9). Two clusters were evident for this site separated by a squared Euclidean distance of 15. The fenced hog (N+S) and control (N+S) were in a separate cluster from the open hog (N+S) suggesting that the open hog plot was significantly different to the control and fenced hog at this site (Figure 12). Site 5 had one soil series a Savannah (Ultisol) and the plots appeared to fall in this soil series (Figure 10). Cluster analyses grouped the open hog (N), open hog (S) and control (N) in one cluster and the fenced hog (N), fenced hog (S) and control (S) in two different clusters

(Figure 12) suggesting that while the open hog and control plots were similar the fenced hog plot was dissimilar.

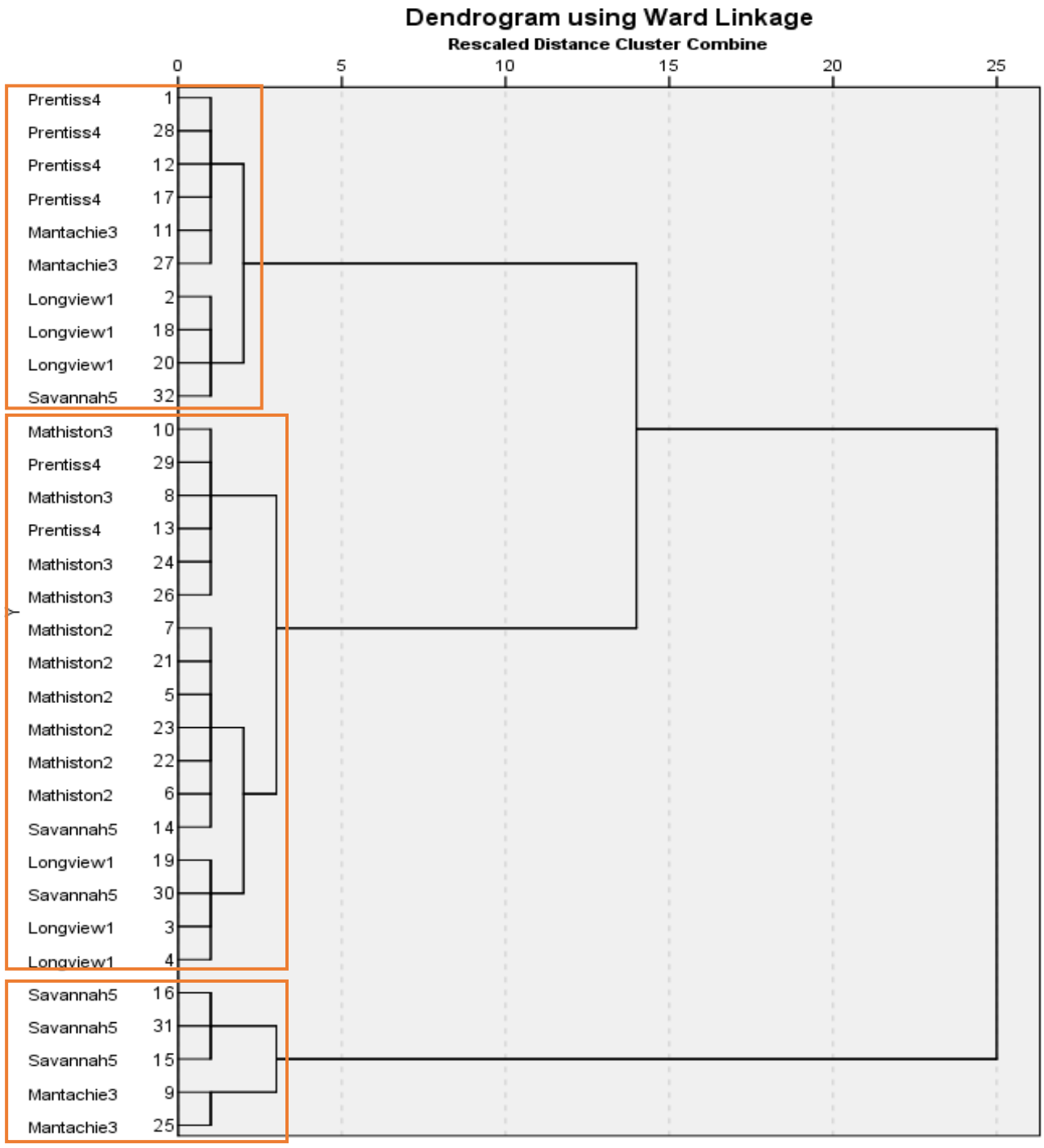

Figure 12. Results of the cluster analyses as a confirmatory method that control and hog soils at each site were similar. Left axis shows soil series followed by site number. The closer the

vertical lines are to zero then the smaller squared Euclidean distance indicating that soils are similar. Oranges boxes show acceptable similarities.

2.2.4 Soil Processing for Wet Chemical Analyses

Samples were air-dried and sieved to 2 mm. 3.5 g of each sieved soil was placed into a high-density polyethylene (HDPE) centrifuge tube with 35 g ultra-pure water. Centrifuge tubes were placed on a rotary shaker for 20 hours at approximately 50 rpm and then centrifuged for 15 minutes at 19,974 g-force. Electrical conductivity and pH of the (1:10 soil:water) extracts were taken with laboratory probes on unfiltered supernatant for each sample. Supernatant extracts were filtered under vacuum using a Whatman GF/F filter (nominal pore size 0.7 µm) to remove any floating organic matter particles. Extracts were diluted with ultra-pure water (1:1 by weight) and analyzed immediately for NO_3-N, NH_4-N, total dissolved nitrogen (TDN), dissolved organic carbon (DOC), orthophosphate-phosphorus (PO_4-P), and $SUVA_{254}$.

2.2.5 Chemical Analyses of Carbon and Nutrients in Soil Extracts

DOC and TDN were measured using high-temperature Pt-catalyzed combustion with a Shimadzu TOC-VCSH and Shimadzu total measuring unit TNM-1 (Shimadzu Corp. Houston, TX, USA). DOC was measured as non-purgeable carbon using EPA Method 415.1, which entails acidifying the sample (2 M HCl to pH 2) and sparging it for 4 minutes with carbon-free air followed by the high temperature combustion. Colorimetic analyses included NH_4-N, analyzed using the phenate hypochlorite method with sodium nitroprusside enhancement (EPA Method 350.1), NO_3-N analyzed using cadmium-copper reduction (EPA Method 353.3), and PO_4-P quantified using the ascorbic acid, molybdate blue method. All colorimetric methods were performed with a Smartchem Discrete Analyzer (Model 200 Westco Scientific Instruments Inc., Brookfield, CT, USA). Dissolved organic nitrogen (DON) is the difference of total dissolved

nitrogen and the sum of NH_4-N and NO_3-N [TDN – (NH_4-N + NO_3-N)]. NIST traceable standards, laboratory standards, replicate samples and water blanks were run every 10 to 12 samples to monitor instrument precision and accuracy. $SUVA_{254}$, a measure of refractory carbon, was analyzed using a Shimadzu Spectrophotometer Model UV-1280. The SUVA value was calculated after normalizing UV absorption (Equation 1).

$$SUVA = 100 \times UV_{abs}/b \times DOC \qquad \text{(Eq. 1)}$$

Where: SUVA is specific ultraviolet absorption (L mg^{-1} C m^{-1}), UV abs is ultraviolet absorption at 254 nm, *b* is the path length of the UV (1 cm), DOC is C concentration (mg C L^{-1}).

2.2.6 Statistical Analyses

Because of the different soil orders and soil series among the five sites at the John Starr forest, the initial approach was to analyze each site individually. Different statistical analyses and numbers of replicates were used depending upon the hypothesis set:

H_{O1}: There is no significant difference between C, N, P concentrations in the CDI of hog plots versus control plots: To test this hypothesis, 15 replicate samples for each plot were used in a 2-sample, 2 tailed T-Test.

H_1: There is a significant increase in all nutrient concentrations in the CDI of hog plots compared to control plots due to the purging of nutrients from the cadavers: To test this hypothesis, 15 replicate samples for each plot were used in a 2-sample, 1 tailed T-Test.

H_{O2} There will be no significant difference in nutrient concentrations when comparing hog decomposition plots fenced or open to scavengers: To test this hypothesis, 15 replicate samples for each plot at each individual site were used in a 2-sample, 2 tailed T-Test.

H_2 There will be significantly higher water extractable nutrients in plots protected from scavengers because scavengers will disperse carrion resulting in a wider spread but lower concentration

H_3 Hog plots will have a defined CDI such that nutrients will be higher beneath the center plot positions and show translocation down the soil profile: To test this hypothesis, 3 replicate samples for each of the three depth increments at each treatment plot and site were used in a 2-sample, 1-tailed T-Test. The three replicate samples were the center point (C) and point either side (1.5N and 1.5S).

H_{O3} There will be no effect of hog mass on nutrients analyzed: To test this hypothesis, nutrient concentration in control soils were deducted from nutrient concentrations in the hog soils. The difference was assumed to be attributed to hog decomposition leachate. Univariate analyses of variance with 2 treatments (open to or fenced from scavengers) and 5 mass values were used as independent variables. 15 replicates per plot were used for each of the 2 treatments at each of the 5 mass sites.

2.3 RESULTS

2.3.1 Lateral and Vertical Extent of Decomposition Products in Soil

2.3.1.1 Site 1: 25 kg Feral Hog

The range for pH was 4.6±0.4 for the fenced hog to 4.9±0.4 for the control; there was no significant difference in pH among the three plots. EC ranged from 8.1±3.0 in the control plot to 16.9±16.9 µS cm^{-1} fenced hog plot and was significantly higher in both the open and fenced plots when compared to the control (Fig. 13A). NO_3-N ranged from 0.4±0.2 to 0.6±0.4 µg g^{-1} in the control and open hog plots respectively but there was no significant difference when

comparing the hog plots and control (Fig. 13B). NH_4-N ranged from 0.8±0.9 in the control to 1.6±1.1 µg g^{-1} in the open hog plot; both the hog plots had significantly higher NH_4-N when compared to the control (Fig. 13C) but were not significantly different from each other (p = 0.44). PO_4-P ranged from 0.2±0.2 to 0.5±0.6 µg g^{-1}in the control and open hog plots respectively; the open hog plot had significantly higher PO_4-P concentration when compared to the control plot (p = 0.03) but there was no significant difference among the two hog plots (Fig. 13D; p = 0.25). While DOC concentrations were significantly higher in both hog plots compared to the control (Open = 165.8±90.9 µg g^{-1}; Fenced = 165±101.6 µg $g^{-1}$and Control = 79.1±57.3 µg g^{-1}) there was no significant difference in DOC concentration among the hog plots (Figure 13E; p = 0.98). Similar to DOC, DON was significantly higher in both hog plots when compared to the control (Fig. 13F; p = 0.03 – 0.003) with DON concentrations ranging from 3.6±2.6 to 8.5±5.6 µg g^{-1} in the control and open hog plots respectively. $SUVA_{254}$ was significantly lower in the fenced hog plot when compared to the control plot (p = 0.045) with values of 3.9±1.6 compared to 8.9±10.9 L mg C^{-1} m^{-1} respectively. Analyses of variance found that treatment at Site 1 had a significant effect on NH_4-N (p = 0.046), DOC p = 0.01) and DON (p = 0.04).

Translocation of DOC down the soil profile was most evident (Fig. 13E) in both the open and fenced hog plots. DOC was significantly higher in both the 10-20 cm and 20-30 cm fractions when compared to the control (p = 0.02).

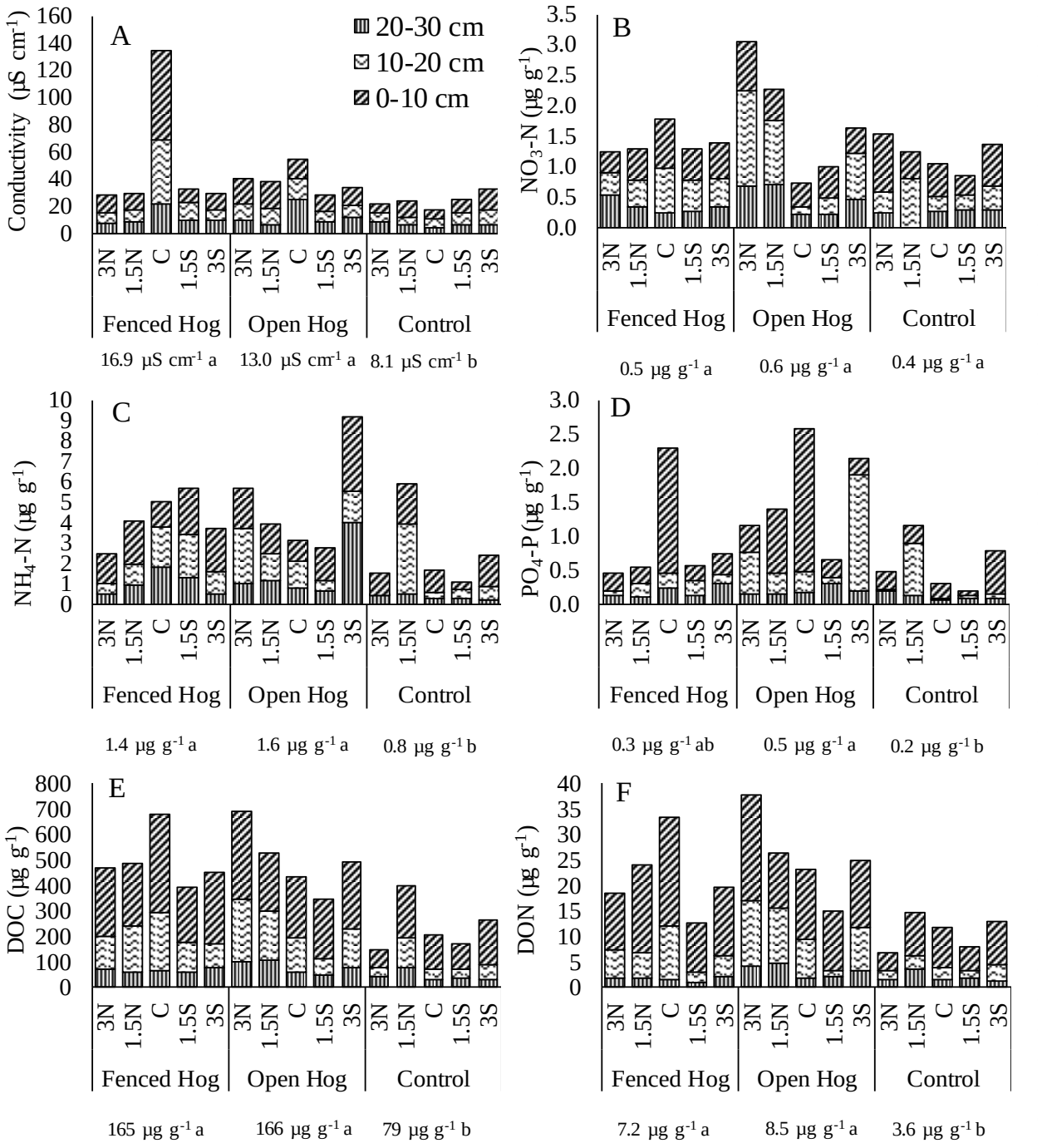

Figure 13. Nutrient concentrations in the Site 1 (25 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n =

15). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

2.3.1.2 Site 2: 59 kg Feral Hogs

The range for pH was 4.6±0.1 for the control to 4.7±0.2 for the fenced hog; there was no significant difference in pH among the three plots. EC ranged from 9.5±3.5 µS cm^{-1} in the control plot to 19.1±5.7 µS cm^{-1} in the open hog plot and was significantly higher in the open hog plot when compared to the control (Fig. 14A). There was no significant difference when comparing EC in the two hog plots (Fig. 14A). NO_3-N ranged from 0.05±0.2 µg g^{-1} to 0.4±0.1 µg g^{-1} in the open hog and control plots respectively. Both hog plots displayed significantly lower NO_3-N concentrations when compared to the control (Fig. 14B; $p < 0.0001$) but there was no significant difference when comparing the hog plots. Ammonium-N ranged from 1.1±0.5 µg g^{-1} in the control to 1.5±0.4 µg g^{-1} in the fenced hog plot; only the fenced hog plot had significantly higher NH_4-N concentrations when compared to the control (Fig. 14C; $p = 0.03$) but the hog plots were not significantly different from each other ($p = 0.43$). PO_4-P ranged from 0.2±0.1 µg g^{-1} to 0.8±0.2 µg g^{-1} in the open hog and control plots respectively; the control plot had significantly higher PO_4-P concentration when compared to the hog plots ($p < 0.001$) and the fenced hog plot had significantly higher PO_4-P when compared to the open hog plot (Fig. 14D; $p = 0.002$). Dissolved organic carbon concentrations ranged from 191±114 µg g^{-1} to 223±96 µg g^{-1} in the control and open hog plots respectively (Fig. 14E) but there was no significant difference in DOC in the plots. Concentrations of DON ranged from 9.4±4.5 µg g^{-1} to 10.5±4.9 µg g^{-1} in the fenced hog and open hog plots respectively and like DOC, there was no significant difference in DON among plots (Fig. 14F). $SUVA_{254}$ was significantly lower in the open hog plot when compared to the control plot ($p < 0.001$) with values of 2.1±0.8 L mg C^{-1}

m^{-1} compared to 3.8±1.1 L mg C^{-1} m^{-1} respectively. There was a significant difference in $SUVA_{254}$ when comparing the hog plots with the fenced hog having a significantly higher $SUVA_{254}$ ($p = 0.01$). Analyses of variance found that treatment at Site 2 had a significant effect on EC ($p = 0.003$), NO_3-N ($p < 0.001$), PO_4-P ($p < 0.001$) and $SUVA_{254}$ ($p = 0.002$).

In terms of nutrient translocation, NH_4-N in the fenced hog plot was significantly higher than the control at both the 10-20 and 20-30 cm depths (Fig. 14C). Significantly lower concentrations of PO_4-P were observed in the fenced hog plot at 10-20 cm ($p < 0.001$) and 20-30 cm ($p < 0.05$) when compared to the control (Fig. 14D). In the open hog plot, translocation down the soil profile was evident for EC at both 10-20 and 20-30 cm and was significantly higher than the control at those depths (Fig. 14A). NO_3-N was significantly lower than the control at 10-20 cm (Fig. 14B) and PO_4-P significantly lower than the control at both the 10-20 and 20-30 cm depths (Fig. 14D). At the 20-30 cm depth, DOC was significantly higher than the control (Fig. 14E).

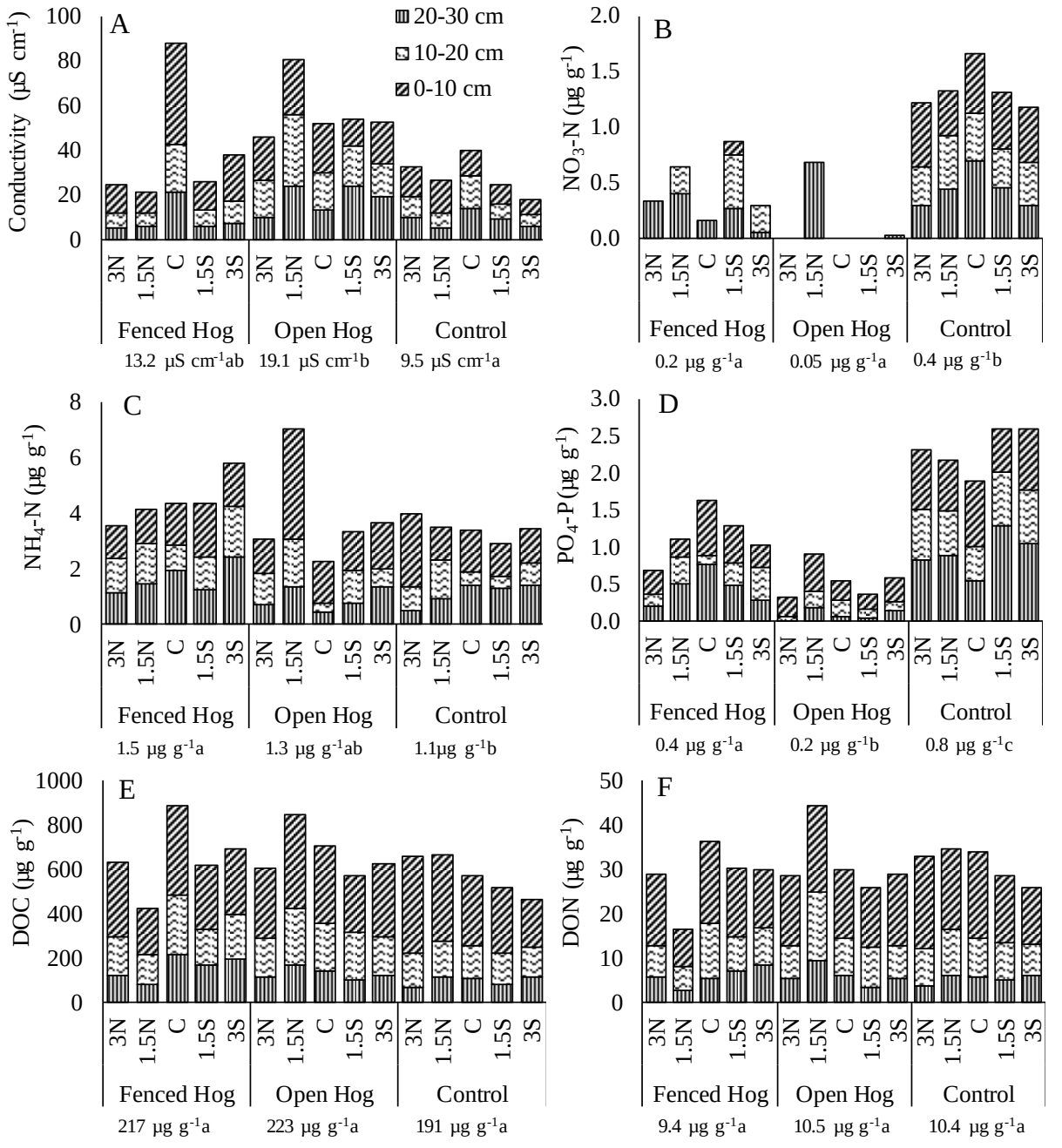

Figure 14. Nutrient concentrations in the Site 2 (59 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n = 15)). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

2.3.1.3 Site 3: 181 kg Feral Hogs

This site had two different soil series. The fenced plots were Mathiston series and the open plots were Mantachie series. There were control plots for both soil series. The range for pH was 4.7±0.2 for the fenced hog to 4.8±0.2 for its control; the range for pH was 4.8±0.2 for the open hog to 4.9±0.3 for its control. There was no significant difference in pH among any plots. EC ranged from 5.7±1.7 µS cm^{-1} in the fenced control plot to 11.9±11 µS cm^{-1} in the fenced hog plot; the range for EC was 4.6±2.0 µS cm^{-1} in the open control plot to 17.3±8.2 µS cm^{-1} in the open hog plot. Both hog plots showed significantly higher EC than their respective controls (Fig. 15A). NO_3-N ranged from 0.16±0.2 µg g^{-1} in the fenced control to 1.9±4.3 µg g^{-1} in the fenced hog; the range for NO_3-N was 0.66±0.3 µg g^{-1} in the open hog plot to 0.30±0.1 µg g^{-1} in the open control plot. Only the hog fenced plot showed significantly higher NO_3-N than its respective control plot (Fig. 15B). NH_4-N ranged from 0.59±1.7 µg g^{-1} in the fenced control plot to 2.0±1.4 µg g^{-1} in the fenced hog plot; the range for NH_4-N was 0.36±0.8 µg g^{-1} in the open control plot to 1.6±0.7 µg g^{-1} in the open hog plot. Both hog plots were significantly higher in NH_4-N than their respective control plots (Fig. 15C). PO_4-P ranged from 0.59±0.3 µg g^{-1} in the fenced control plot to 0.97±2.7 µg g^{-1} in the fenced hog plot; the range for PO_4-P was 0.35±0.4 µg g^{-1} in the open control plot to 0.36±0.5 µg g^{-1} in the open hog plot. There was no significant difference in PO_4-P for any plots (Figure 15D). DOC, and DON did not show significant differences between hog plots and their respective controls (Fig. 16A-B).

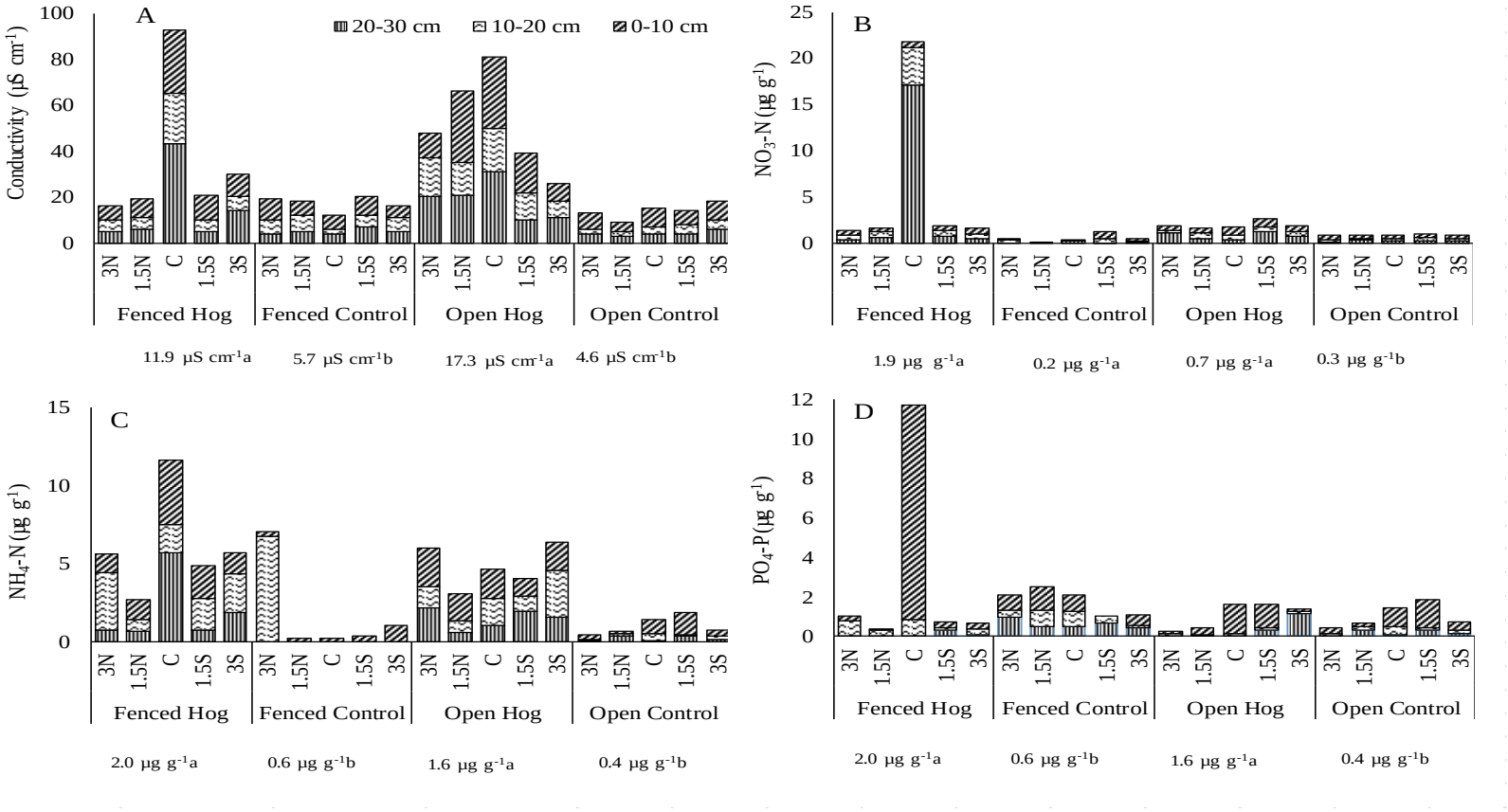

Figure 15. Nutrient concentrations in the Site 3 (181 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n = 15)). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

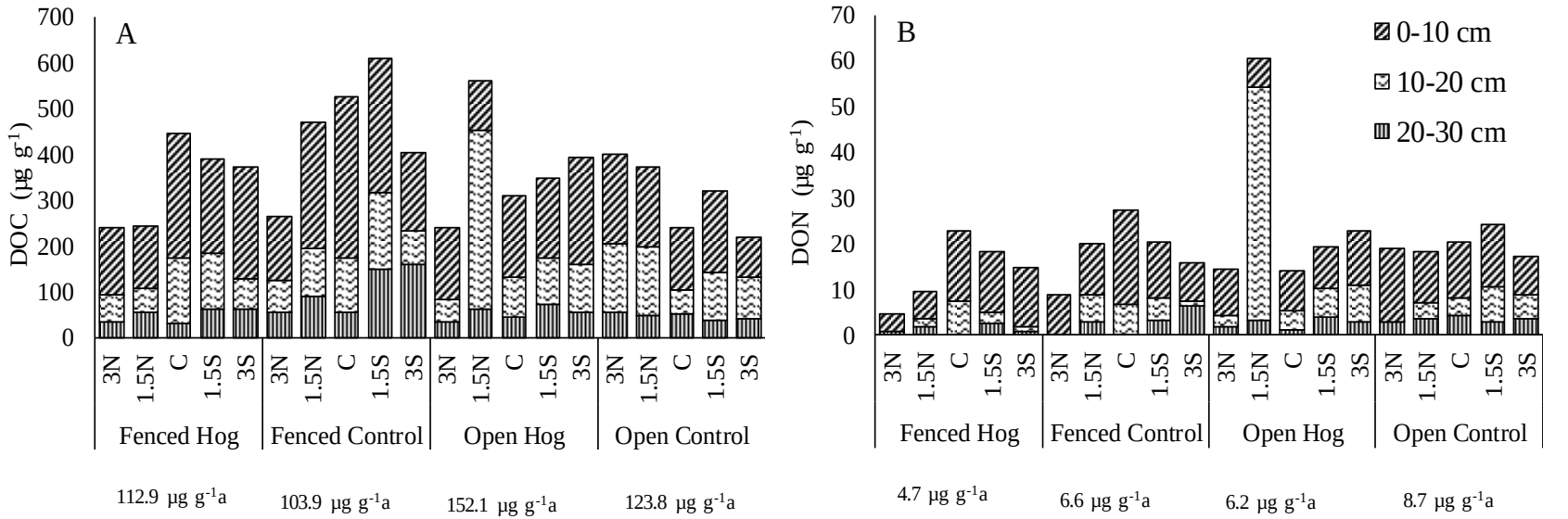

Figure 16. Nutrient concentrations in the Site 3 (181 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n = 15)). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

2.3.1.4 Site 4: 363 kg Feral Hogs

The range for pH was 4.6±0.28 for the fenced hog plot to 5.2±0.28 for the control; both hog plots were significantly lower than the control plot at this site. EC ranged from 3.1±2.6 µS cm^{-1} at the control plot to 27.7±28.5 µS cm^{-1} at the fenced hog plot; both hog plots were significantly higher than the control plot (Fig. 17A). NO_3-N ranged from 3.8±8.8 µg g^{-1} at the control plot to 244.8±43.5 µg g^{-1} at the open hog plot; both hog plots were significantly higher than the control plot (Fig. 17B). Furthermore, the open hog plot was significantly higher in NO_3-N than the fenced hog plot (244.8±43.5 µg g^{-1} and 94.6±44.9 µg g^{-1}, respectively) (Fig. 17B). NH_4-N ranged from 0.24±0.37 µg g^{-1} at the control plot to 8.4±9.0 µg g^{-1} at the fenced hog plot; both hog plots were significantly higher than the control plot, the fenced hog plot was significantly higher in NH_4-N than the open hog plot (8.4±9.0 µg g^{-1} and 2.1±1.1 µg g^{-1}, respectively) (Fig. 17C). PO_4-P ranged from 0.11±0.24 µg g^{-1} in the control plot to 1.38±3.61 µg g^{-1} in the open hog plot; neither hog plot was significantly different than the control (Figure 17D). No significant differences were observed for DON, however, DOC ranged from 59±18 µg g^{-1} in the control to 154±93 µg g^{-1} in the open hog plot. Both hog plots were significantly higher in DOC than the control (Fig. 17E) but no significant differences were found between fenced hog and open hog plots. $SUVA_{254}$ ranged from 2.9±0.86 µg g^{-1} in the open hog plot to 9.6±3.2 µg g^{-1} in the control plot; both hog plots were significantly lower than the control plot. $SUVA_{254}$ was also significantly higher in the fenced hog plot than the open hog plot (4.8±2.3 µg g^{-1} and 2.9±0.86 µg g^{-1}, respectively). Analyses of variance found that treatment at Site 4 had a significant effect on pH, EC, NO_3-N, NH_4-N, DOC, and $SUVA_{254}$.

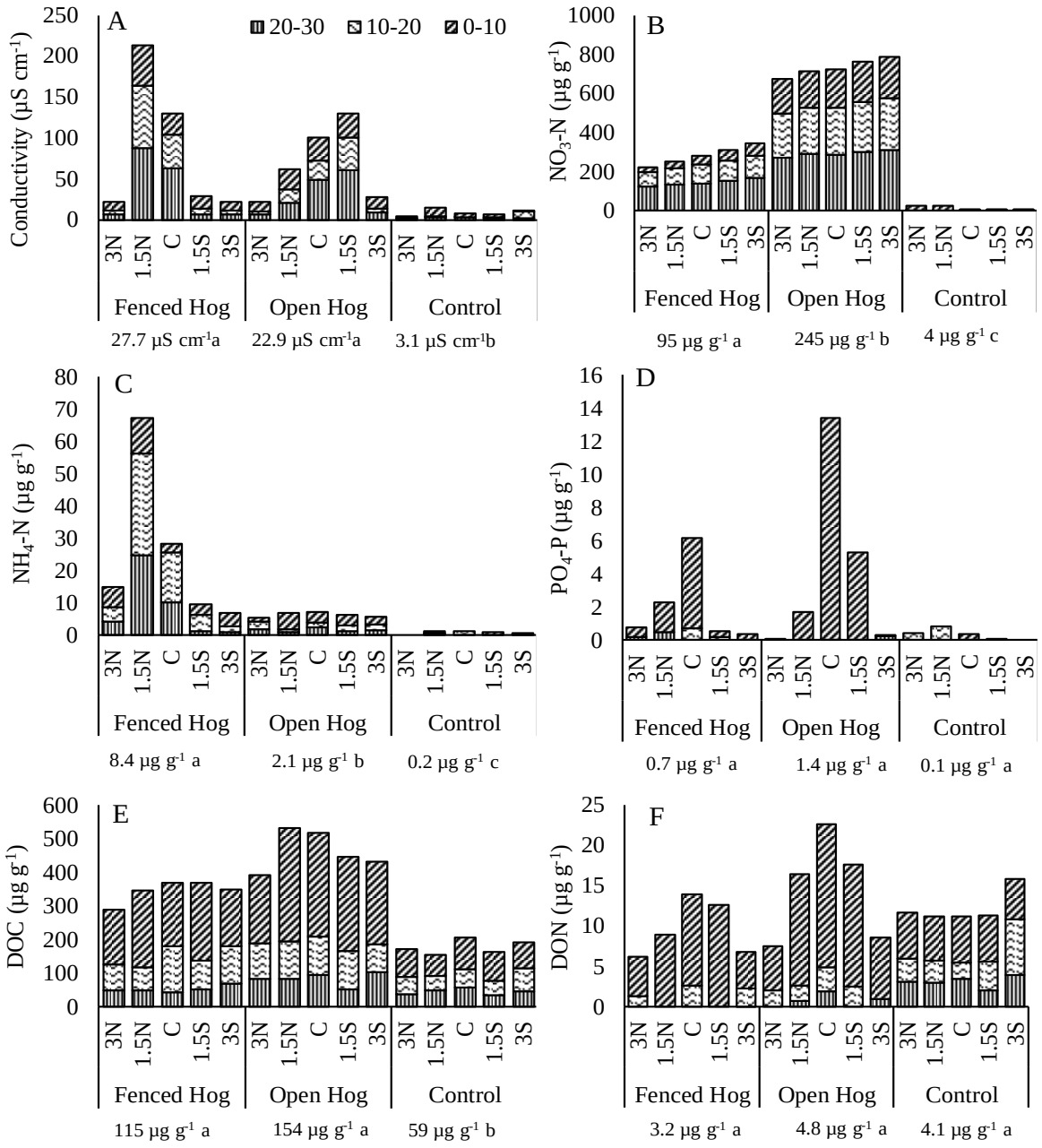

Figure 17. Nutrient concentrations in the Site 4 (363 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n = 15)). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

2.3.1.5 Site 5: 725 kg Feral Hogs

The range for pH was 4.9±0.2 for the fenced hog plot to 5.4±0.2 for the control plot; both fenced and open hog plots had significantly lower pH than the control plot ($p < 0.01$). EC ranged from 5±2 µS cm^{-1} at the control plot to 40±42 µS cm^{-1} at the fenced hog plot; both fenced and open hog plots had significantly higher EC when compared to the control (Fig. 18A). NO_3-N ranged from 0.9±0.3 µg g^{-1}in the control plot to 23±31 µg g^{-1}in at the fenced hog plot; the fenced hog plot was significantly higher in NO_3-N than the control and open hog plot (Fig. 18B). NH_4-N ranged from 3.1±2.5 µg g^{-1}at the control plot to 17±22 µg g^{-1}at the fenced hog plot; the fenced hog plot was significantly higher in NH_4-N than both the control and the open hog plots (Fig. 18C). PO_4-P ranged from 0.2±0.1 µg g^{-1}at the control to 3.7±7.3 µg g^{-1}at the open hog plot; both the open hog plot and fenced hog (2.0±3.5 µg g^{-1}) plot were significantly higher than the control (Fig. 18D) but neither hog plots were significantly different from each other. DOC and DON were not significantly different when compared to the control or each other (Fig. 18E-F). DOC ranged from 138±61 µg g^{-1} at the open hog plot to 150±90 µg g^{-1} at the fenced hog plot. DON ranged from 4.6±5.0 µg g^{-1} at the fenced hog plot to 6.3±4.3 µg g^{-1} at the control plot (Fig.18F). $SUVA_{254}$ values ranged from 6.8±3.1 L mg C^{-1} m^{-1} at the open hog plot to 11.3±7.0 L mg C^{-1} m^{-1} at the fenced hog plot. $SUVA_{254}$ for the control was 8.9±4.4 L mg C^{-1} m^{-1}.

Analyses of variance found that treatment at Site 5 had a significant effect on pH, NO_3-N and NH_4-N.

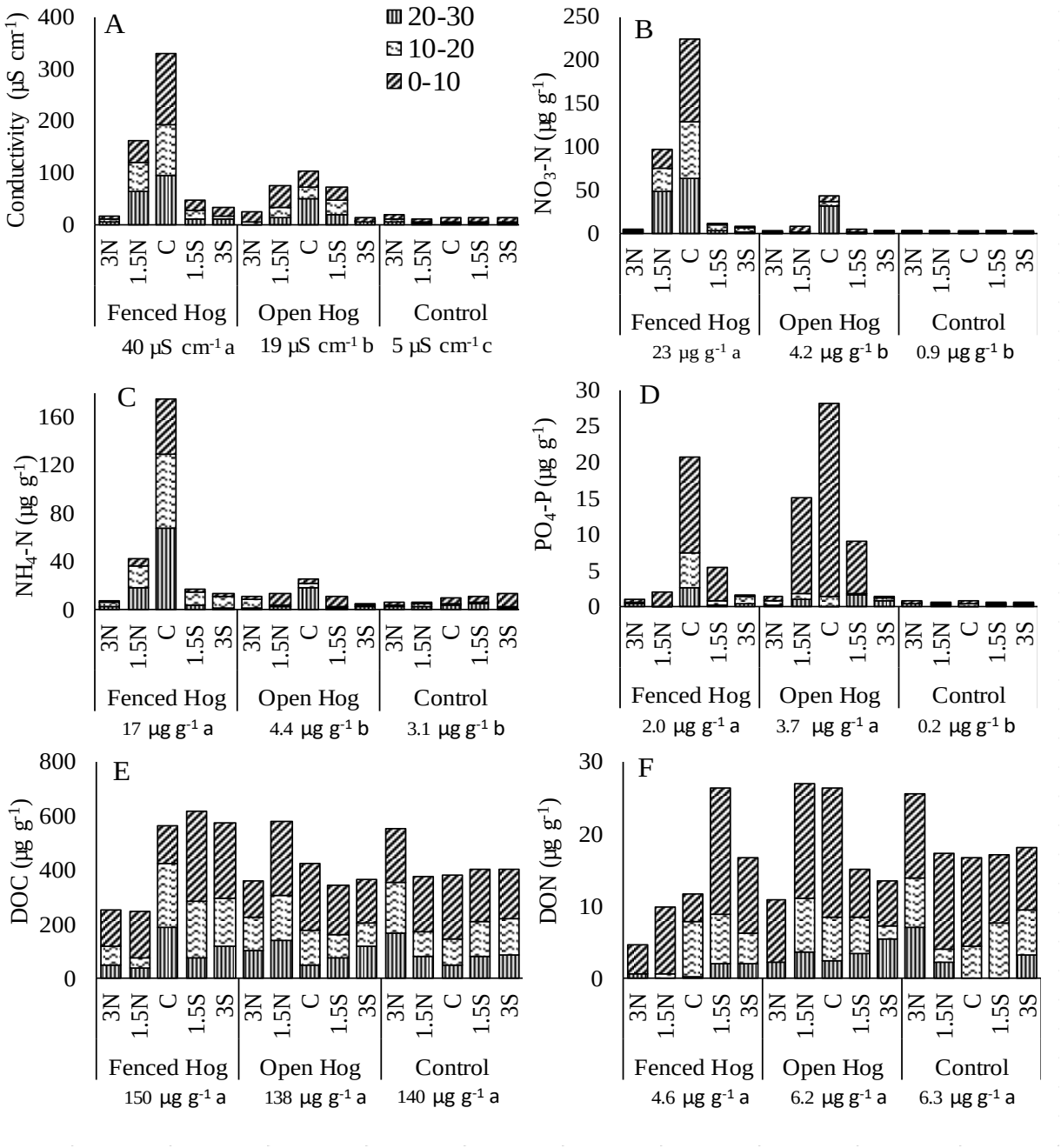

Figure 18. Nutrient concentrations in the Site 5 (725 kg) hog and control plots. Fenced hog are protected from scavengers and Open Hog are open to scavengers. Concentrations beneath the x-axis are the mean concentration for that plot (averaged over all sampling points and depths (n = 15)). Different lower case letters by mean concentrations indicate significant difference for that specific nutrient among treatments. Sampling positions in the CDI are 3N to 3S.

Effect of decomposition products on water extractable soil chemistry at depths

Prior statistical analyses examined whether significant differences existed in soil nutrient chemistry on a treatment plot basis using 15 replicates for each treatment at each site. These next analyses examined nutrient chemistry on a depth basis at each plot and at each site to determine if there were significant differences in nutrient chemistry at each of the three depth increments. Because the cadaver decomposition island is typically proportional to the mass of the cadaver and because the decomposition product translocation tends to be centered I used the center sampling point and the two samples either side of center for analyses. Thus for each depth increment at each plot there are 3 replicates. Means and standard deviation were calculated (Tables 2-6) and 2-sample 1-tailed t-tests were performed to test the hypothesis that CDI chemistry was significantly different from controls at each depth increment, and 2-sample, 2-tailed t-tests to test the hypothesis that there would be no significant difference in the CDIs of the hog plots due to scavenging.

2.3.2.1 Site 1

0-10 cm depth

At 10 cm depth there was no significant difference in pH, NO_3-N, NH_4-N or PO_4-P when comparing nutrients from the CDI plots to the control plot (Table 2). Conductivity was significantly higher in the open hog CDI compared to control ($p = 0.04$). There was no significant difference when comparing the fenced hog and control ($p = 0.17$) or the two CDIs ($p = 0.49$) for conductivity. NH_4-N was significantly higher in the fenced hog plot when compared to the control ($p < 0.05$). Both DOC and DON were significantly higher in both hog plots compared to the control plot (Table 2) but were not significantly different from each other.

10-20 cm depth

At a depth of 10-20 cm in the CDI of a 25 kg cadaver no significant difference was found for pH, EC, NO_3-N, NH_4-N, PO_4-P, DON or $SUVA_{254}$ (Table 2). However DOC was significantly increased in the fenced hog compared to the control (173±56 ug g^{-1} vs 65±46 ug g^{-1}; p = 0.03; Table 2).

20-30 cm depth

At a depth of 20-30 cm, no significant difference was observed for EC, NO_3-N, DOC, DON or $SUVA_{254}$ (Table 2). Significant differences at the depth increment were observed for pH, ammonium-N and orthophosphate-P (Table 2). Neither the fenced hog or open hog had significantly different pH from the control but they were significantly different from each other (p = 0.02). Both the open hog and fenced hog had significantly increased NH_4-N concentration when compared to control (p < 0.05) and the open hog plot had significantly higher PO_4-P when compared to the control (p = 0.04).

2.3.2.2 Site 2

0-10 cm depth

At 10 cm depth there was no significant difference in hog CDI chemistry when compared to control for pH, EC, NH_4-N, DOC or DON (Table 3). NO_3-N and PO_4-P concentration was significantly lower in the open hog plot when compared to control (p < 0.001 and 0.02). $SUVA_{254}$ was significantly lower in both hog CDIs when compared to control and the hog plots were significantly different from each other.

10-20 cm depth

At 20 cm depth there was no significant difference between hog CDI chemistry and control for pH, NH_4-N, or DON (Table 3). EC was significantly higher in the open hog CDI compared to the control plot (Table 3). NO_3-N was significantly lower in the open hog CDI compared to the control plot ($p < 0.01$). PO_4-P was significantly lower in both hog CDIs compared to the control plot ($p < 0.01$). DOC was significantly higher in the open hog CDI compared to the control ($p < 0.01$). $SUVA_{254}$ in the open hog CDI was significantly lower than the control plot ($p < 0.01$).

20-30 cm depth

At the 30 cm depth there were no significant differences between hog CDI chemistry and control for NH_4-N, DOC, or DON (Table 3). EC was significantly higher in the open hog CDI than the control plot ($p < 0.05$). NO_3-N was significantly lower in the fenced hog CDI compared to the control ($p < 0.05$). PO_4-P was significantly lower in the open hog CDI compared to the control ($p < 0.01$) and significantly lower than the fenced hog CDI ($p < 0.05$). $SUVA_{254}$ was significantly lower in the open hog CDI compared to the control ($p < 0.05$) and significantly lower than the fenced hog CDI ($p < 0.05$).

Table 2. Effect of decomposition products on soil chemistry at the three depth increments at Site 1. Values in parenthesis are standard deviation. Different lower case letters indicate significant difference at $p < 0.5$ within each depth increment.

Soil Order	Depth	Treatment	pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$
	cm			$\mu S\ cm^{-1}$			$\mu g\ g^{-1}$			$L\ mg\ C^{-1}\ m^{-1}$
Alfisol	10	Fenced Hog	4.7a	29.3ab	0.6a	1.9a	0.8a	282a	16.1a	3.7ab
			(0.2)	(31.8)	(0.2)	(0.5)	(0.9)	(90)	(6.0)	(0.4)
	10	Open Hog	4.7a	15.3b	0.5a	1.4ab	1.1a	234a	12.2a	3.4b
			(0.1)	(3.5)	(0.1)	(0.3)	(0.9)	(8)	(1.6)	(0.5)
	10	Control	4.7a	9.7a	0.4a	1.1b	0.2a	147b	7.0b	6.5a
			(0.1)	(2.5)	(0.1)	(0.8)	(0.1)	(56)	(2.1)	(2.3)
	20	Fenced Hog	4.5a	22.7a	0.6a	1.7a	0.2a	173a	5.8a	4.8a
			(0.2)	(21.2)	(0.1)	(0.6)	(0.0)	(56)	(4.3)	(1.3)
	20	Open Hog	4.6a	11.3a	0.5a	1.0a	0.2a	131ab	6.4a	5.6a
			(0.1)	(4.0)	(0.5)	(0.5)	(0.1)	(66)	(4.8)	(4.2)
	20	Control	4.8a	6.7a	0.4a	1.4a	0.3a	65b	2.1a	12.3a
			(0.2)	(1.5)	(0.3)	(1.7)	(0.4)	(46)	(0.6)	(13.1)
	30	Fenced Hog	4.4a	13.7a	0.3a	1.3a	0.2ab	62a	1.4a	2.4a
			(0.1)	(7.2)	(0.1)	(0.4)	(0.1)	(3)	(0.5)	(1.3)
	30	Open Hog	4.8b	13.7a	0.4a	0.9a	0.2a	71a	2.9a	3.2a
			(0.1)	(9.9)	(0.3)	(0.2)	(0.1)	(29)	(1.6)	(3.9)
	30	Control	4.7ab	6.0a	0.2a	0.3b	0.1b	45a	2.3a	3.6a
			(0.2)	(1.7)	(0.2)	(0.2)	(0.0)	(25)	(1.1)	(3.6)

Table 3. Effect of decomposition products on soil chemistry at the three depth increments at Site 2. Values in parenthesis are standard deviation. Different lower case letters indicate significant difference at $p < 0.05$ within each depth increment.

Soil Order	Depth	Treatment	pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$
	cm			$\mu S\ cm^{-1}$			$\mu g\ g^{-1}$			$L\ mg\ C^{-1}\ m^{-1}$
	10	Fenced Hog	4.6a	22.3a	0.0ab	1.5a	0.5ab	299a	15.6a	2.3a
			(0.3)	(19.7)	(0.1)	(0.3)	(0.2)	(98)	(5.1)	(0.3)
	10	Open Hog	4.6a	19.7a	0.0b	2.3a	0.3b	343a	18.3a	1.4b
			(0.1)	(6.8)	(0.0)	(1.5)	(0.2)	(85)	(3.1)	(0.2)
	10	Control	4.5a	11.7a	0.5a	1.3a	0.7a	334a	19.4a	3.0c
			(0.0)	(3.1)	(0.1)	(0.2)	(0.1)	(51)	(2.2)	(0.5)
	20	Fenced Hog	4.7a	11.7ab	0.2ab	1.2a	0.3a	188ab	9.8a	4.2ab
			(0.3)	(9.0)	(0.2)	(0.3)	(0.1)	(70)	(3.6)	(2.4)
Entisol	20	Open Hog	4.6a	22.3a	0.0b	1.1a	0.2a	226b	12.1a	2.0b
			(0.1)	(8.4)	(0.0)	(0.7)	(0.0)	(22)	(3.8)	(0.2)
	20	Control	4.6a	9.7b	0.4a	0.8a	0.6b	149a	10.3a	4.6a
			(0.1)	(4.6)	(0.1)	(0.6)	(0.1)	(11)	(1.0)	(0.9)
	30	Fenced Hog	4.8a	11.0ab	0.3a	1.5a	0.6a	155a	6.9a	7.0a
			(0.3)	(8.7)	(0.1)	(0.3)	(0.2)	(68)	(2.2)	(2.7)
	30	Open Hog	4.6a	20.3a	0.2ab	0.8a	0.1b	136b	7.3a	2.2b
			(0.1)	(6.4)	(0.4)	(0.4)	(0.1)	(33)	(2.9)	(0.8)
	30	Control	4.8a	9.3b	0.5b	1.2a	0.9a	102c	8.3a	4.8a
			(0.2)	(4.5)	(0.1)	(0.3)	(0.4)	(16)	(0.6)	(1.8)

2.3.2.3 Site 3

0-10 cm depth

At the 10 cm depth there were no significant differences in hog CDI chemistry and control for pH or PO_4-P (Table 4). EC was significantly higher in the open hog CDI than the open control ($p < 0.01$). NO_3-N was significantly higher in the open hog CDI than the open control (Table 4). NH_4-N was significantly higher in the fenced hog CDI than the fenced control ($p < 0.05$). DOC was significantly higher in the open hog CDI than the open control ($p < 0.01$). DON was significantly higher in the open hog CDI than the open control (Table 4).

10-20 cm depth

At the 20 cm depth there were no significant differences for pH, PO_4-P, DOC, DON, or $SUVA_{254}$ (Table 4). NO_3-N was significantly higher in the open hog CDI compared to its control ($p < 0.05$). Both hog plots were significantly higher than their respective controls for NH_4-N but not significantly different from each other ($p < 0.01$; Table 4).

20-30 cm depth

At the 30 cm depth there were no significant differences for pH, NO_3-N, DOC, and $SUVA_{254}$ (Table 4). EC was significantly higher at the open hog CDI than the control ($p < 0.01$). NH_4-N was significantly higher at the open hog CDI than the control ($p < 0.05$). PO_4-P was significantly higher at the fenced hog CDI than the fenced control ($p < 0.01$). DON was significantly lower at the fenced hog CDI than the fenced control (Table 4).

2.3.2.4 Site 4

0-10 cm depth

At the 10 cm depth there were no significant differences between hog CDI chemistry and control (Table 5). pH was significantly higher at the control compared to the open hog CDI ($p < 0.05$). EC was significantly higher at the fenced hog CDI compared to the control ($p < 0.05$) and the open hog CDI was significantly higher than the control ($p < 0.01$) but neither hog CDI plots were significantly different from each other. NO_3-N was significantly higher at the fenced hog CDI compared to the control (Table 5) and significantly higher at the open hog CDI compared to the control ($p < 0.01$). The open hog CDI was also significantly higher than the fenced hog CDI ($p < 0.01$). NH_4-N was significantly higher at the open hog CDI compared to the control ($p < 0.01$). Both fenced hog and open hog CDIs were significantly higher in DOC than the control ($p < 0.01$) however, the open hog CDI was significantly higher in DOC than the fenced hog CDI ($p < 0.01$). DON was also significantly higher in both fenced hog CDI and open hog CDI than the control ($p < 0.01$) however, open hog CDI showed significantly higher DON than the fenced hog CDI (Table 5). $SUVA_{245}$ was significantly lower in fenced hog CDI than the control (Table 5) and significantly lower in the open hog CDI than the control ($p < 0.01$).

10-20 cm depth

At the 20 cm depth, PO_4-P and DON showed no significant differences between either hog CDIs or the control (Table 5). pH was significantly lower at the fenced hog CDI than the control (Table 5) and significantly lower at the open hog CDI than the control ($p < 0.01$). EC was significantly higher at the open hog CDI than the control ($p < 0.01$). NO_3-N was significantly higher at both hog CDIs compared to the control ($p < 0.01$) however, the open hog CDI was significantly higher in NO_3-N than the fenced hog CDI ($p < 0.01$). Both the fenced hog CDI and the open hog CDI were significantly higher than the control (Table 5). DOC was significantly higher at the fenced hog CDI than the control ($p < 0.05$) and significantly higher at the open hog

CDI than the control ($p < 0.01$). $SUVA_{254}$ was significantly higher at the fenced hog CDI than the control (Table 5) and significantly higher at the open hog CDI than the control ($p < 0.01$).

20-30 cm depth

At the 30 cm depth, there were no significant differences between hog CDIs and control for PO_4-P and DOC (Table 5). pH was significantly lower at both hog CDIs compared to the control ($p < 0.01$). EC was significantly higher at the open hog CDI compared to the control ($p < 0.01$). NO_3-N was significantly higher at both hog CDIs compared to the control ($p < 0.01$) however, the open hog CDI was significantly higher than the fenced hog CDI ($p < 0.01$). Similar to EC, NH_4-N was significantly higher at the open hog CDI compared to the control (Table 5). DON was significantly lower at the fenced hog CDI compared to the control ($p < 0.01$) and significantly lower at the open hog CDI compared to the control ($p < 0.05$). $SUVA_{254}$ was significantly higher at both hog CDI than the control ($p < 0.01$).

2.3.2.5 Site 5

0-10 cm depth

At the 10 cm depth, NH_4-N, DOC, and $SUVA_{254}$ showed no significant differences for either fenced hog, open hog, or control (Table 6). pH at the fenced hog CDI was significantly lower than the control ($p < 0.01$) and the open hog CDI was significantly lower than the control ($p < 0.05$). EC was significantly higher at the open hog CDI than the control ($p < 0.01$). NO_3-N was significantly higher at the open hog CDI than the control ($p < 0.01$). PO_4-P was also significantly higher at the open hog CDI than the control (Table 6).

10-20 cm depth

At the 20 cm depth there were no significant differences for NO_3-N, NH_4-N, PO_4-P, DOC, DON or $SUVA_{254}$ (Table 6). pH was significantly lower at both hog CDI compared to the control ($p < 0.01$). EC was significantly higher at the fenced hog CDI compared to the control (Table 6) and significantly higher at the open hog CDI compared to the control ($p < 0.01$).

20-30 cm depth

At the 30 cm depth there were no significant differences between the hog CDIs or when comparing the hog CDIs to the control for pH, NO_3-N, NH_4-N, PO_4-P, or DOC (Table 6). EC was significantly higher at both hog CDIs compared to the control ($p < 0.05$). DON was significantly higher at the open hog CDI than the control ($p < 0.05$) and the open hog CDI was also significantly higher than the fenced hog CDI ($p < 0.05$). $SUVA_{254}$ was significantly lower at the open hog CDI than the control (Table 6).

Table 4. Effect of decomposition products on soil chemistry at the three depth increments at Site 3. Values in parenthesis are standard deviation. Different lower case letters indicate significant difference at $p < 0.05$ within each depth increment.

Soil Order	Depth cm		pH	EC $\mu S\ cm^{-1}$	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$ $L\ mg\ C^{-1}\ m^{-1}$
							$\mu g\ g^{-1}$			
Inceptisol & Entisol	10	Fenced Hog	4.7a	15.7a	0.5a	2.5a	3.7a	205a	11.4a	2.4a
			(0.1)	(10.8)	(0.1)	(1.5)	(6.2)	(69)	(5.0)	(0.5)
	10	Open Hog	4.9b	26.3b	0.7b	1.6c	1.0b	307b	14.8b	1.5b
			(0.3)	(8.1)	(0.2)	(0.4)	(0.6)	(42)	(5.1)	(0.1)
	10	Fenced Control	4.9a	6.7a	0.2a	0.3b	0.7a	164a	12.2a	3.1a
			(0.1)	(1.2)	(0.4)	(0.1)	(0.6)	(23)	(1.3)	(0.8)
	10	Open Control	5.1b	6.0c	0.4c	1.5c	0.8b	155c	7.9c	2.5b
			(0.7)	(2.0)	(0.1)	(1.4)	(0.6)	(0)	(1.5)	(0.9)
	20	Fenced Hog	4.7a	10.7a	1.8a	1.5a	0.4a	105a	4.0a	5.6a
			(0.2)	(9.8)	(2.0)	(0.7)	(0.4)	(47)	(3.0)	(3.9)
	20	Open Hog	4.8b	15.0b	0.6b	1.2c	0.1b	131b	5.7b	2.5b
			(0.1)	(3.6)	(0.1)	(0.5)	(0.0)	(33)	(1.0)	(0.5)
	20	Fenced Control	4.7a	4.7a	0.2a	0.0b	0.6a	102a	5.2a	4.1a
			(0.1)	(2.5)	(0.3)	(0.0)	(0.3)	(50)	(2.3)	(2.2)
	20	Open Control	5.0b	3.0c	0.2c	0.0d	0.2b	193b	20.6b	2.2b
			(0.2)	(1.0)	(0.1)	(0.0)	(0.1)	(173)	(26.4)	(1.5)
	30	Fenced Hog	4.6a	18.0a	6.2a	2.4a	0.1a	50a	1.4a	3.1a
			(0.2)	(21.7)	(9.4)	(2.9)	(0.2)	(17)	(1.3)	(3.1)
	30	Open Hog	4.8b	20.7b	0.7b	1.2b	0.1c	99b	2.2c	1.5b
			(0.0)	(10.5)	(0.5)	(0.7)	(0.2)	(8)	(1.9)	(1.3)
	30	Fenced Control	4.8a	5.3a	0.1a	0.0a	0.5b	46a	3.6b	4.7a
			(0.2)	(1.5)	(0.1)	(0.0)	(0.1)	(8)	(0.6)	(1.4)
	30	Open Control	4.9b	3.7c	0.3c	0.0c	0.3c	59b	2.8c	3.1b
			(0.3)	(0.6)	(0.1)	(0.0)	(0.1)	(15)	(1.4)	(1.1)

Table 5. Effect of decomposition products on soil chemistry at the three depth increments at Site 4. Values in parenthesis are standard deviation. Different lower case letters indicate significant difference at $p < 0.05$ within each individual depth increment.

Soil Order	Depth cm	Treatment	pH	EC µS/cm	NO_3-N	NH_4-N	PO_4-P µg/g	DOC	DON	$SUVA_{254}$ L mg C^{-1} m^{-1}
	10	Fenced Hog	4.8ab	30.0a	45.1a	5.7ab	2.5a	215a	10.9a	3.5a
			(0.1)	(17.3)	(11.5)	(4.6)	(2.6)	(22)	(1.9)	(0.5)
	10	Open Hog	4.4b	27.0a	196.1b	3.8b	6.8a	307b	15.5b	2.7a
			(0.2)	(2.6)	(10.1)	(1.2)	(6.0)	(28)	(1.9)	(0.2)
	10	Control	5.1a	6.0b	9.1c	0.5a	0.1a	80c	5.6c	6.9b
			(0.3)	(3.5)	(15.3)	(0.4)	(0.2)	(18)	(0.1)	(1.8)
	20	Fenced Hog	4.6a	41.3ab	94.5a	17.3a	0.3a	98a	0.9a	6.6a
			(0.3)	(3.5)	(9.7)	(13.3)	(0.4)	(34)	(1.5)	(4.3)
Ultisol	20	Open Hog	4.5a	27.0b	246.0b	1.5a	0.0a	114a	2.5a	2.8a
			(0.1)	(11.8)	(10.9)	(0.4)	(0.0)	(2)	(0.5)	(0.1)
	20	Control	5.2b	1.3a	0.6c	0.5b	0.3a	47b	2.8a	13.5b
			(0.3)	(0.6)	(0.4)	(0.6)	(0.5)	(6)	(0.8)	(1.7)
	30	Fenced Hog	4.6a	52.7ab	143.6a	12.0ab	0.2a	48a	0.0a	3.0a
			(0.2)	(41.5)	(8.7)	(11.9)	(0.3)	(4)	(0.0)	(0.8)
	30	Open Hog	4.4a	43.7b	293.6b	1.4b	0.0a	77a	0.9a	2.6a
			(0.2)	(20.5)	(6.0)	(0.8)	(0.0)	(22)	(1.0)	(0.5)
	30	Control	5.4b	2.7a	0.4c	0.1a	0.0a	48a	2.8b	10.0b
			(0.2)	(0.6)	(0.1)	(0.1)	(0.0)	(11)	(0.7)	(1.5)

Table 6. Effect of decomposition products on soil chemistry at the three depth increments at Site 5. Values in parenthesis are standard deviation. Different lower case letters indicate significant difference at $p < 0.05$ within each individual depth increment.

Soil Order	Depth cm		pH	EC µS/cm	NO_3-N	NH_4-N	PO_4-P µg/g	DOC	DON	$SUVA_{254}$ L mg C^{-1} m^{-1}
Ultisol	10	Fenced Hog	4.8a	67.3ab	39.1ab	18.4a	6.6ab	215a	10.3a	7.8a
			(0.1)	(61.2)	(49.4)	(24.0)	(5.9)	(103)	(7.0)	(2.1)
	10	Open Hog	4.9a	32.3b	5.6a	7.1a	15.7a	234a	13.4a	5.0a
			(0.2)	(7.1)	(1.8)	(3.6)	(9.9)	(48)	(6.0)	(1.2)
	10	Control	5.3b	7.0a	0.9b	3.6a	0.3b	209a	11.6a	5.5a
			(0.2)	(2.0)	(0.2)	(1.9)	(0.0)	(22)	(2.1)	(0.6)
	20	Fenced Hog	4.9a	56.7a	32.5a	29.9a	1.9a	160a	5.0a	8.8
			(0.1)	(42.5)	(29.6)	(27.3)	(2.6)	(106)	(3.9)	(5.4)
	20	Open Hog	4.7a	23.7a	2.5a	1.9a	0.9a	127a	6.2a	6.5
			(0.1)	(4.0)	(3.0)	(1.2)	(0.6)	(39)	(1.2)	(2.5)
	20	Control	5.5b	3.3b	1.1a	2.2a	0.3a	107a	4.7a	12.4
			(0.2)	(0.6)	(0.0)	(0.7)	(0.1)	(22)	(3.0)	(4.9)
	30	Fenced Hog	4.9a	57.0a	39.1a	29.8a	0.9a	99a	0.7a	9.2ab
			(0.3)	(41.6)	(31.5)	(33.3)	(1.4)	(79)	(1.0)	(8.6)
	30	Open Hog	4.9a	28.3a	11.3a	7.5a	0.9a	87a	3.2b	6.3b
			(0.2)	(18.9)	(17.8)	(9.7)	(0.8)	(47)	(0.6)	(3.4)
	30	Control	5.4a	3.0b	1.0a	3.3a	0.1a	70a	0.8a	13.3a
			(0.3)	(1.0)	(0.4)	(1.2)	(0.1)	(20)	(1.3)	(3.1)

2.3.2 Effect of Mass Analyses

By deducting the water extractable nutrient values of the control plots from their respective hog plots, left are the assumed decomposition contributions to soil nutrients (Table 7).

This exercise enabled an approximation of the effect of hog mass and treatment (whether hogs were protected from scavengers (fenced) or open to scavengers (open) on water extractable soil chemistry.

Univariate analyses of variance was used to assess the effect of hog mass and treatment (fenced or open) and whether there was a significant interaction effect of mass and treatment on decomposition product chemistry.

Table 7. Average decomposition product chemistry (n=15) for fenced and open hog sites and their masses. Negative values are those where the hog plots had lower nutrient chemistry when compared to control plots.

Mass kg	TMT	NO_3-N	NH_4-N	PO_4-P	DOC	TDN	DON
				$\mu g\ g^{-1}$			
25	Fenced	0.06	0.56	0.11	85.95	4.21	3.59
59	Fenced	-0.29	0.33	-0.39	25.21	-0.92	-0.96
181	Fenced	0.58	0.86	-0.58	-48.59	-10.65	-12.09
363	Fenced	90.78	8.20	0.56	55.47	21.26	-0.86
725	Fenced	22.02	13.85	1.81	9.81	34.17	-1.69
25	Open	0.18	0.81	0.34	86.71	5.85	4.87
59	Open	-0.40	0.14	-0.59	31.57	-0.16	0.10
181	Open	-0.10	2.43	-0.18	-17.55	1.06	-1.27
363	Open	240.93	1.82	1.27	95.12	8.52	0.77
725	Open	3.26	1.21	3.44	-2.71	4.33	-0.15

There was a significant effect of mass ($p < 0.001$) and treatment ($p < 0.001$) and an interaction effect of mass and treatment on water extractable NO_3-N ($p < 0.001$). A significant

effect of mass ($p = 0.001$), treatment ($p = 0.004$) and a significant interaction effect was also observed for NH_4-N ($p = 0.006$). For PO_4-P there was a significant effect of mass ($p = 0.005$) but no effect of treatment ($p = 0.41$) or interaction effect of mass and treatment ($p = 0.69$). A significant effect of mass was observed for both DOC and DON ($p < 0.001$) but there was no significant effect of treatment ($p = 0.39$ DOC and 0.29 DON) or significant interaction between treatment and mass ($p = 0.75$ DOC and 0.93 DON).

2.4 DISCUSSION

Reporting of mass mortality events (MME) for wildlife is increasing (Fey et al. 2015; McCallum 2015; Kock et al. 2018). Furthermore, deaths of livestock can also present an environmental issue in terms of changes in soil chemistry (Chowdbury et al. 2019). Whether mass mortality events are a function of better reporting or climate change parameters is currently debateable. A secondary type of MME would be due to the intentional baiting and killing of wildlife that are a nuisance species such as feral hogs and leaving them in place. Based on prior studies of CDI chemistry from beneath humans (Aitkenhead-Peterson et al. 2012, 2015; Fancher et al. 2016) and other mammals (Anderson et al. 2013; Towne 2000, Szelecz et al. 2018), it was imperative to determine how different masses of feral hogs in a secondary MME scenario might impact water extractable soil nutrients. Of specific interest was whether fencing off hogs, or leaving them open to scavengers would have a significant effect on soil nutrient chemistry.

2.4.1 pH

Soil pH often increases immediately after purge of a cadaver and then decreases which is postulated to be due to the influx of organic acids into the soil (Aitkenhead-Peterson et al. 2012; Fancher et al. 2017). Aitkenhead-Peterson et al. (2012) reported significantly lower pH in the

CDI of 2 human cadavers at 248 and 288 d since placement compared to control soil in a forested soil in Texas. Pringle et al. (2010) reported a huge variability in pH in the CDI of domestic swine. In my study, only in Sites 4 and 5 hog plots had significantly lower pH when compared to their respective controls which may be due to soil recovery after 613 d since cadaver placement for those masses ≤ 181 kg.

2.4.2 Electrical Conductivity

Electrical conductivity of soil in the CDI typically increases due to the large input of purge fluids and appears to return to ambient values in the 0-5 cm depth in human CDI at around 690 d since placement (Fancher et al. 2017). Control soil EC in the Fancher et al. (2017) study was 105 and 126 µS cm^{-1} for the two soils examined, much higher than EC observed in control soils at 0-10 cm depth for my study where they were < 10 µS cm^{-1}. Both the Fancher et al. (2017) and my study used the same protocol and instruments for CDI analyses. I did however observe significantly increased EC at all the hog sites relative to their control sites. Although Kwon et al. (2017) reported EC values from swine mortality leachate in groundwater, they too found that EC significantly increased at livestock carcass burial site (5780 µS cm^{-1}) compared to their control site (100 µS cm^{-1}). Interestingly, in my study, Sites 2 & 3 showed a higher mean EC at the open hog plots (19.1 µS cm^{-1} and 17.3 µS cm^{-1}) than at the fenced hog plots (13.2 µS cm^{-1} and 11.9 µS cm^{-1}), this may be due to potential fecal contamination from scavenging activities.

2.4.3 NO_3-N

NO_3-N is typically lower in the CDI soil of human cadavers for at least a year post purge (Aitkenhead-Peterson et al. 2015). Purge fluids cause a saturation of soil and anaerobic conditions prevail which means that oxygen in soil pores is severely limited for microbial

processing of the influx of decomposition products. At the advanced decomposition stage, anions such as cadaveric NO_3^-, SO_4^{2-} and HCO_3^- will be used by soil microorganisms for respiration (Aitkenhead-Peterson et al. 2012). Initial significantly lower NO_3-N has been reported in the CDI soil of several human cadaver studies where soil was taken from undisturbed CDI at depths of either 0-5 or 0-7 cm. (Aitkenhead-Peterson et al. 2012, 2015; Fancher et al. 2017) Reports of NO_3-N from CDI under domestic swine are variable. For example, Anderson et al. (2013) reported that NO_3-N concentrations at 0-5 cm depth one year after placement were significantly higher than control soils and at three years after placement NO_3-N concentrations at 0-5 cm depth were not significantly different from control soils. Szelecz et al. (2018) examined decomposition products in the CDI of domestic swine (27.8±0.8 kg) over 10 sampling periods for a period of one year; depth of soil samples was 0-10 cm and 10 (6 cm x 10 cm) samples were removed, mixed and sub-sampled on each sampling period. They reported a significant increase of NO_3-N in the CDI (9.37±1.5 μg g^{-1}) compared to control (3.35±0.37 μg g^{-1}) at the end of their year-long study with NO_3-N peaking at only 59 d after placement (Szelecz et al. 2018). Under human cadavers sampled at 0-7 cm depth nitrate peaks did not occur until 408 d after placement (Aitkenhead-Peterson et al 2015). Aeration of the soil by continual sampling such as in the Szelecz et al. (2018) study would have initiated aerobic conditions earlier in the study initiating an early nitrification. In my study, a fenced 25 kg feral hog had much lower concentrations of NO_3-N which ranged 0.55 μg g^{-1} (0-10 cm), 0.51 μg g^{-1} (10-20 cm) and 0.35 μg g^{-1} (20-30 cm) compared to controls which ranged 0.59, 0.40 and 0.22 μg g^{-1} for 0-10, 10-20 and 20-30 cm respectively, with no significant difference observed between fenced hog and controls. It may be that at 18 months, NO_3-N in the MME project had recovered to ambient concentrations. Because the transformation of NH_4-N to NO_3-N occurs under aerobic conditions, it can be expected that

NO_3-N concentration will only increase in CDI soil once the soil becomes aerated through root growth, animal burrowing or other disturbances.

2.4.4 NH_4-N

NH_4-N in the CDI of human cadaver CDI is typically extremely high after purge and the concentration only drops once soil is aerated and the conversion of NH_4-N to NO_3-N is observed. Aitkenhead-Peterson et al. (2015) reported concentrations of approximately 700 µg g^{-1} above control soil concentration at 90 d since placement at a 0-7 cm depth in the CDI of humans. Fancher et al (2017) reported NH_4-N concentrations of 9 to 111 µg g^{-1}at 0-5 cm; 1 to 86 µg g^{-1} at 5-10 cm and 2 to 57 µg g^{-1}at 10-15 cm compared to 7 to 5, 1 to 8 and 2 to 3 µg g^{-1} in control soils at the same depths. Time since placement in the Fancher et al. (2017) for the three depths ranged from 406 to 1114 d since placement. In the CDI of domestic swine, Szelecz et al. (2018) reported an average (over the course of a one-year study) NH_4-N concentration of 391.9 mg kg^{-1} at 0-10 cm in a fenced domestic swine CDI compared to 12.5 mg kg^{-1} in control soils at the same depth (Table 9). Anderson et al. (2013) reported concentrations of 9 mg kg^{-1} compared to 5 mg kg^{-1} at a depth of 0-5 cm in the CDI of domestic swine (Table 9). In my MME study the NH_4-N concentration in the CDI beneath one 25 kg feral hog was 1.9 mg kg^{-}compared to 1.1 mg $kg^{-}$for control soils at 0-10 cm depth (Table 9) at approximately 613 d since placement.

Table 8. Concentrations of nutrients in the soil beneath decomposing wildlife and domestic livestock. ‡Average of 1 year.

Cite Code	Cadaver	Mass	Sample Depth	Land use	PMI	Extract	Ratio	Carbon	Nitrogen			Phosphorus
								DOC	DON	NO_3-N	NH_4-N	PO_4-P
		kg	cm		d					mg/kg		
This Study	FH	25	0-10	FF	613	DDW	1:10	282.4a	16.1a	0.6a	1.9a	0.8a
					Control			147.1b	6.9b	0.4a	1.1a	0.2a
		59			613			298.8a	14.0a	0.0a	1.5a	0.5a
					Control			334.2a	17.6a	0.5a	1.3a	0.7a
		181			613			204.6a	11.4a	0.5a	2.5a	3.7a
					Control			164.2a	12.2a	0.2a	0.3b	0.7a
		363			613			215.5a	10.9a	45.1a	5.7a	2.5a
					Control			80.2b	5.6b	9.1b	0.5a	0.1a
		725			613			215.3a	10.3a	39.0a	18.3a	6.6a
					Control			208.5a	11.6a	0.9a	3.6a	0.3a
1	DS	20	0-5	FG	365	DDW	1:05			12.25a	7a	
					1095					1.75b	9a	
					Control					1.95b	5a	
2	B+C	>318	0-10	OP	365	1N KCl	nd			625a		
					Control					25b		
					728					275a		
					Control					15b		
3	DS	27.8	0-10	FF	365‡	DDW	nd			41.4a	391.9a	
					Control					14.8b	12.57b	

Cadaver: FH=Feral Hog, DS=Domestic Swine, B=Bison, C=Cattle. Landuse and Treatment: FF=Fenced Forest, FG=Fenced Grassland; OP=Open Prairie. Cite Code: 1 = Anderson et al. 2013; 2 = Towne 2000; 3 = Szelecz et al. (2018)

2.4.5 PO_4-P

Pratt & Fonstad (2017b) showed pure leachate from 5,900 kg of swine carcasses to contain phosphorus at an average concentration of 1,930 mg L^{-1} with a maximum concentration of 1870 mg L^{-1} and a low concentration of 1,300 mg L^{-1}. Their study was able to monitor phosphorus fluctuations in swine leachate over a period of 25 months post burial and revealed slight fluctuations at early sampling dates to a balanced concentration by approximately 14 months. Though my study did not cover multiple periods of time, nor pure leachate, it can be noted that exposure of leachate to a soils natural environmental may play an important part in reducing nutrient concentrations in decomposition leachate. In my study, PO_4-P concentrations were higher at sites > 59kg hog weight at 0-10 cm (Table 9) but were not significantly different from control sites at the same depth (Table 9) Scavenging appeared to increase PO_4-P concentrations which is feasible due to fecal deposition.

2.4.6 DOC

Historically organic matter decomposition has focused on the decomposition of terrestrial plant material (e.g. Nadelhoffer et al. 2004). Dead plant biomass, is defined by Benbow et al. (2019) as autotrophically derived decomposing organic matter. Benbow et al. (2019) suggested that plant material and fecal matter are not the only forms of detritus that are recycled in soil and that another source, carrion has an equally important ecosystem function. Barton et al. (2019) postulated that while decomposition of plant material is recognized, decomposition of carrion is poorly understood. Bump et al (2009) determined that lasting biogeochemical hotspots of soil nutrients maintain plant biodiversity based on a study of deer carrion decomposition. Human donor facilities have facilitated studies on soil nutrients but with a forensic objective. Currently there are seven operational donor facilities in the USA; the first a facility run by the University

of Tennessee which opened in 1981 and the most recent a facility run by the University of South Florida which opened in 2018.

Dissolved organic carbon concentrations retrieved from the CDI of decomposing humans are typically significantly higher than their respective control soils (Aitkenhead-Peterson et al. 2012) and have been observed to reach concentrations of around 6,000 µg g^{-1} at between 176-196 d since placement (Aitkenhead-Peterson et al. 2015). In the Fancher et al. (2017) study, DOC concentrations reached 10,000 µg g^{-1} during early decomposition at a 0-5 cm soil depth. For domestic swine, Szelecz et al. 2018 reported no significant difference in percent soil carbon when comparing control and CDI over a 1 year experiment. Heo (2016) examined single domestic swine CDI over a 180 d experimental period and reported peak water extractable DOC occurring at 21 d since placement at a concentration of 6,000 µg g^{-1} at 0-10 cm depth. Chowdbury et al. (2019) examined the leachate from livestock domestic swine (average weight 12 kg) to assess the impact of decomposition product C and N on soil. They reported a concentration of 34,000 mg L^{-1} total organic carbon in leachate. While DOC can be considered a substrate for soil microbes and much of it mineralized to CO_2 or other volatile organic compounds (e.g. Statheropoulos et al. 2005), DOC does appear to be persistent in the soil beneath human cadavers up to 1752 d at a depth of 0-5 cm (Fancher et al., 2017) but its persistence may be a factor of the prior diet of the deceased. Results for water extractable DOC from the CDI of in my study for feral hogs was mixed. There was significantly higher DOC in the CDI of 25 kg and 363 kg hog cadaver mass at 613 d since placement at 0-10 cm depth but not for the other hog cadaver masses (Table 9). This lack of DOC persistence may be due to the diet of hogs compared to the western diet of humans which may contain compounds such as per- (all carbon atoms are bonded with fluorine) and poly- (not all carbon atoms are bonded with

fluorine) fluoroalkyls (PFAS) which are resistant to degradation, have low volatility and are water soluble; furthermore they are bioaccumulated in those with a diet of fast-food (Gibbens 2019).

2.4.7 DON

DON has been extensively identified and measured in soil studies of forests (McDowell et al., 1998 and Qualls et al. 2000) and agricultural settings (Chardon et al., 1997 and Murphy et al., 2000). DON prevalence and importance in animal decomposition research, though, remains minimally studied. Aitkenhead-Peterson et al. 2015, however, found that DON tended to increase in the CDI of human cadavers approximately up to 196 days PMI and then decrease over time. Furthermore, Aitkenhead-Peterson et al. (2015) explained that both mineralization (DON to NH_4-N) and immobilization (NH_4-N to DON) may occur after 176 days PMI. DON in open hog plots seemed to be very close to the ambient soil conditions of the control soils at all sites except for Site 1. DON was also lower in fenced hog plots than any open hog plots at all sites and subsequently the fenced hog plots showed the highest NH_4-N concentrations at all sites except for Site 1. This suggests that scavenging helped immobilize NH_4-N to DON and mitigate the effects of NH_4-N nutrient contamination from decomposition leachate back to normal soil conditions.

2.4.8 $SUVA_{254}$

$SUVA_{254}$ has typically been utilized in surface water chemistry to assess the potential for increased aromatics in surface waters (Weishaar et al. 2003). By default, low values of $SUVA_{254}$ generally suggest that DOC molecules that are not aromatic and are likely to biodegrade at a faster rate. Mao et al. (2017) reported an inverse relationship between biodegradable DOC and

$SUVA_{254}$ in surface and soil pore waters exposed to long term application of phosphorus. Aitkenhead-Peterson (unpublished) also found a strong and significant inverse relationship between percent biodegradable DOC (%BDOC) and $SUVA_{254}$ in water extractable samples taken from human CDI ($R^2 = 0.85$; $p = 0.009$). For a control soil the $SUVA_{254}$ value was 2.6 and %BDOC was 47.9% , for a CDI soil the $SUVA_{254}$ value was 5.4 and the %BDOC was 33.9% (Aitkenhead-Peterson unpublished). $SUVA_{254}$ values in the control soil in my study tended to be significantly higher than those for the hog soil in some sites (Table 10) suggesting that feral hogs may provide a useable C substrate for soil microbes compared to human cadavers. Forest soil typically has more aromatic-C derived from the forest floor compared to other types of land uses which would increase its $SUVA_{254}$ value and decrease its biodegradability (McDowell et al. 2006). It is expected that wildlife will have less aromatic-C in their decomposition products compared to other mammals fed a very different diet.

2.4.9 Effect of mass on soil chemistry

Several studies have examined the effect of mass on carrion decomposition (Brand, 2008; Komar & Beatie 1998; Matuszewski, Konwerski, Fratczak 2014; Spicka, Johnson, Bushing, Higley, Carter 2011). Carcass mass had a significant effect on the onset of advanced decay in domestic swine; with bloating starting earlier on larger carcasses and onset of advanced decay starting earlier on smaller carcasses (Matuszewski et al. 2014). The CDI represents the purge of nutrients from the body after bloating is complete. Spicka et al. (2011) examined the effect of carcass mass on decomposition rate and production of ninhydrin reactive nitrogen (NRN) on an alfisol in Nebraska, USA. They used masses from 1 kg (neonate) to 50 kg (adult) domestic swine. Greatest mass loss occurred with 8 d for 20, 40 and 50 kg swine (Spicka et al. 2011). Furthermore, NRN was significantly higher in the 20, 40 and 50 kg CDI than in the CDI beneath

the neonate (Spicka et al. 2011). In my study, the trend was the greater the hog mass, the greater the NO_3-N and/or NH_4-N, as well as PO_4-P. Indeed, hog mass had a significant effect on all nutrients analyzed in my study.

Table 9. $SUVA_{254}$ (mg C^{-1} m^{-1}) values across all five sites. Different lowercase letters show significant difference ($p < 0.05$)

Site	Treatment	Soil Series	SUVA 254
Site 1	Control	Alfisol	8.9±10.9a
	Hog Open	Alfisol	5.6±3.7ab
	Hog Fenced	Alfisol	3.9±1.6b
Site 2	Control	Entisol	3.8±1.1a
	Hog Open	Entisol	2.1±0.8b
	Hog Fenced	Entisol	4.2±2.44a
Site 3	Control Open	Inceptisol	2.3±1.1a
	Hog Open	Inceptisol	1.8±0.9a
	Control Fenced	Entisol	4.1±1.4b
	Hog Fenced	Entisol	3.4±2.3b
Site 4	Control	Ultisol	9.6±3.2a
	Hog Open	Ultisol	3.0±0.9b
	Hog Fenced	Ultisol	4.8±2.3c
Site 5	Control	Ultisol	8.9±4.4ab
	Hog Open	Ultisol	6.8±3.1a
	Hog Fenced	Ultisol	11.3±7.0b

2.4.10 Limitations to study

The major limitation to this study was the lack of consideration for soil series or soil orders for each plot and site. The initial experimental design set up by Mississippi State University researchers simulated an MME to study the effects on an ecosystem in terms of entomology, microbiology, and plant physiology (Lashley et al., 2017; Tomberlin et al. 2017; Wilcox 2017). They likely did not foresee the potential for soil contamination. Despite this, I was able to gather

control soils of the same series for the corresponding sites to complete the framework for my thesis.

2.4.11 Recommendations

Based on my results of a MME experiment in Mississippi, USA, in the event of a baiting and killing feral hogs which would result in MME, the best environment to mitigate nutrient transport through soil would be one similar to that of Site 2 in the study. This soil had the lowest transport of NO_3-N and NH_4-N at open hog plots in the 20-30 cm depth on examination of the center of the CDI. The soil at Site 2 was an Entisol with a 0-2 % slope with approximately 11% sand, 71 % silt, and 18% clay; the lowest sand content of any of the sites.

Allowing for open scavenging of above-ground cadavers will also help mitigate negative environmental and soil health effects. Burying cadavers is not recommended for the same reason as previous pure swine leachate studies have shown throughout this thesis. Additionally, the less hogs culled in one area, the less the environmental impact on soil nutrients should be observed. It is also ideal to cull in areas further from sources of surface water, though this experiment showed the lateral transport of nutrients was not a significant area of concern in the John Starr Forest, if a toxic bait such as sodium nitrite were implemented in a watershed, the effects of the toxin may cause hogs to run to the nearest water source due to extreme thirst before dying shortly thereafter. One can then refer back to previous studies mentioned in this thesis regarding pure swine leachate to understand the impact of that scenario on freshwater.

CHAPTER III

SUMMARY AND CONCLUSIONS

SUMMARY

Mass deaths of livestock can present an environmental issue in terms of changes in soil chemistry (Chowdbury et al. 2019) and overall soil/environmental health. The population of some wildlife species have been increasing and are influenced by factors such as water availability, habitat, lack of competition for resources, and lack of predation or disease. One such wildlife species is feral hogs whose population has proven environmentally and economically detrimental to many states in the US. The baiting and killing of these hogs may contribute to a secondary MME scenario where decomposition products directly impact soil, plant and insect functions in riparian areas and specifically in areas with soils that are conducive to nutrient transport (such as those sites with higher saturated hydraulic conductivity). High cadaver mass sites (greater than 363 kg) pose the greatest environmental impacts for NO_3-N, NH_4-N, and PO_4-P contamination. Allowing uninhibited scavenging activities after baiting and killing hogs, however, reduces the environmental impacts of the aforementioned nutrients.

CONCLUSIONS

- Low cadaver mass decomposition sites, ≤ 181 kg, did not show significant threats to the soil environment based on water extractable nutrient concentrations. However, as cadaver mass on a site was increased, such as in sites 4 and 5 with masses ≥ 363 kg the potential environmental impacts from high NO_3-N, NH_4-N, and PO_4-P are prevalent.
- The depth at which these nutrients can move and remain prevalent in the soil is also concerning particularly when characteristics of the soil are conducive to high transport.

For example, soils with a higher saturated hydraulic conductivity such as sandy soils will likely see nutrient movement to deeper depths.

- Scavenging tended to spread nutrients laterally throughout the experimental plots but the concentrations tended to be lower whereas protected cadavers tended to have a high concentration of nutrients at the center of the CDI.

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APPENDIX A. Raw Data for chemical analyses for all sites used in this study. Type: 1=Hog and 2=Control. Treatment (TMT) F=Fenced from Scavengers and O=Open to scavengers.

								Concentration						
TAMU ID	Site #	Sample	Type	TMT	Position	Depth cm	pH	EC µS/cm	NO_3-N mg/kg	NH_4-N mg/kg	PO_4-P mg/kg	DOC mg/kg	DON mg/kg	$SUVA_{254}$ mg C^{-1} m^{-1}
S07446	1	HFN-10	1	F	-3.05	0-10	4.6	13	0.3	1.4	0.2	270	11.1	2.1
S07447	1	HFNM-10	1	F	-1.52	0-10	4.6	12	0.5	2.1	0.2	248	17.4	3.4
S07448	1	HFC-10	1	F	0	0-10	4.9	66	0.8	1.3	1.8	385	21.3	4.2
S07449	1	HFSM-10	1	F	1.52	0-10	4.5	10	0.5	2.3	0.2	215	9.6	3.5
S07450	1	HFS-10	1	F	3.05	0-10	4.6	12	0.6	2.1	0.3	283	13.6	3.7
S07451	1	HFN-20	1	F	-3.05	10-20	4.6	7	0.4	0.5	0.1	133	5.5	4.1
S07452	1	HFNM-20	1	F	-1.52	10-20	4.7	8	0.4	1.0	0.2	179	4.9	3.4
S07453	1	HFC-20	1	F	0	10-20	4.3	47	0.7	2.0	0.2	226	10.5	5.6
S07454	1	HFSM-20	1	F	1.52	10-20	4.5	13	0.5	2.1	0.2	115	2.0	5.5
S07455	1	HFS-20	1	F	3.05	10-20	4.6	7	0.5	1.1	0.1	88	3.9	5.6
S07456	1	HFN-30	1	F	-3.05	20-30	4.6	8	0.5	0.5	0.1	68	1.8	7.2
S07457	1	HFNM-30	1	F	-1.52	20-30	4.5	9	0.3	1.0	0.1	60	1.8	3.9
S07458	1	HFC-30	1	F	0	20-30	4.3	22	0.2	1.8	0.2	66	1.5	1.3
S07459	1	HFSM-30	1	F	1.52	20-30	4.5	10	0.3	1.3	0.1	61	0.8	2.0
S07460	1	HFS-30	1	F	3.05	20-30	5.9	10	0.3	0.5	0.3	79	2.1	2.7
S07466	1	HUN-10	1	O	-3.05	0-10	4.8	18	0.8	2.0	0.4	346	20.7	3.8
S07467	1	HUNM-10	1	O	-1.52	0-10	4.7	19	0.5	1.5	0.9	225	10.8	3.1
S07468	1	HUC-10	1	O	0	0-10	4.5	15	0.4	1.0	2.1	241	13.9	3.1
S07469	1	HUSM-10	1	O	1.52	0-10	4.8	12	0.5	1.6	0.3	235	11.9	4.0
S07470	1	HUS-10	1	O	3.05	0-10	4.7	13	0.4	3.7	0.2	258	13.1	3.3
S07471	1	HUN-20	1	O	-3.05	10-20	4.7	12	1.6	2.8	0.6	249	12.8	11.1
S07472	1	HUNM-20	1	O	-1.52	10-20	4.7	12	1.1	1.3	0.3	196	10.6	9.4

S07473	1	HUC-20	1	O	0	10-20	4.7	15	0.1	1.3	0.3	131	7.4	6.3
S07474	1	HUSM-20	1	O	1.52	10-20	4.6	7	0.3	0.5	0.1	65	1.2	1.2
S07475	1	HUS-20	1	O	3.05	10-20	5.9	9	0.8	1.5	1.7	154	8.5	11.1
S07476	1	HUN-30	1	O	-3.05	20-30	4.7	10	0.7	1.0	0.2	98	4.2	9.7
S07477	1	HUNM-30	1	O	-1.52	20-30	4.7	7	0.7	1.1	0.2	103	4.7	7.7
S07478	1	HUC-30	1	O	0	20-30	5.0	25	0.2	0.8	0.2	62	1.9	1.4
S07479	1	HUSM-30	1	O	1.52	20-30	4.7	9	0.2	0.6	0.3	47	2.0	0.6
S07480	1	HUS-30	1	O	3.05	20-30	4.9	12	0.5	4.0	0.2	77	3.3	7.7
S07506	1	CUN-10	2	O	-3.05	0-10	4.8	7	0.9	1.1	0.3	69	3.4	39.6
S07507	1	CUNM-10	2	O	-1.52	0-10	4.6	12	0.5	1.9	0.3	208	8.5	4.9
S07508	1	CUC-10	2	O	0	0-10	4.8	7	0.5	1.1	0.2	135	7.9	9.1
S07509	1	CUSM-10	2	O	1.52	0-10	4.6	10	0.3	0.4	0.1	98	4.5	5.5
S07510	1	CUS-10	2	O	3.05	0-10	5.8	16	0.7	1.5	0.6	179	8.6	6.3
S07511	1	CUN-20	2	O	-3.05	10-20	4.6	6	0.3	0.0	0.0	39	1.8	3.5
S07512	1	CUNM-20	2	O	-1.52	10-20	5.0	5	0.8	3.4	0.8	118	2.7	27.4
S07513	1	CUC-20	2	O	0	10-20	4.7	7	0.2	0.3	0.0	40	2.3	6.1
S07514	1	CUSM-20	2	O	1.52	10-20	4.6	8	0.3	0.4	0.0	37	1.4	3.5
S07515	1	CUS-20	2	O	3.05	10-20	4.5	10	0.4	0.7	0.1	58	3.0	7.1
S07516	1	CUN-30	2	O	-3.05	20-30	5.7	9	0.2	0.4	0.2	40	1.6	2.6
S07517	1	CUNM-30	2	O	-1.52	20-30	4.5	7	0.0	0.5	0.1	74	3.6	1.0
S07518	1	CUC-30	2	O	0	20-30	4.7	4	0.3	0.2	0.0	28	1.5	3.5
S07519	1	CUSM-30	2	O	1.52	20-30	4.9	7	0.3	0.3	0.1	35	1.8	6.1
S07520	1	CUS-30	2	O	3.05	20-30	5.0	7	0.3	0.2	0.1	28	1.3	1.4
S07606	2	HFN-10	1	F	-3.05	10	4.6	13	0.0	1.2	0.3	337	15.9	1.7
S07607	2	HFNM-10	1	F	-1.52	10	4.8	9	0.0	1.3	0.3	206	8.5	2.5
S07608	2	HFC-10	1	F	0	10	4.3	45	0.0	1.5	0.7	401	18.5	2.0
S07609	2	HFSM-10	1	F	1.52	10	4.8	13	0.1	1.9	0.5	289	15.2	2.4
S07610	2	HFS-10	1	F	3.05	10	4.5	21	0.0	1.6	0.3	293	13.0	1.5
S07611	2	HFN-20	1	F	-3.05	20	4.6	7	0.0	1.2	0.2	174	7.1	4.0
S07612	2	HFNM-20	1	F	-1.52	20	4.6	6	0.2	1.5	0.3	134	5.2	6.8
S07613	2	HFC-20	1	F	0	20	4.6	22	0.0	1.0	0.1	267	12.3	2.0

S07614	2	HFSM-20	1	F	1.52	20	5.1	7	0.5	1.2	0.3	164	7.6	3.8
S07615	2	HFS-20	1	F	3.05	20	4.5	10	0.2	1.8	0.4	201	8.4	4.7
S07616	2	HFN-30	1	F	-3.05	30	4.7	5	0.3	1.1	0.2	120	5.7	6.4
S07617	2	HFNM-30	1	F	-1.52	30	5.2	6	0.4	1.4	0.5	82	2.8	9.9
S07618	2	HFC-30	1	F	0	30	4.7	21	0.2	1.9	0.8	217	5.3	4.4
S07619	2	HFSM-30	1	F	1.52	30	4.6	6	0.3	1.2	0.5	166	7.2	6.9
S07620	2	HFS-30	1	F	3.05	30	4.6	7	0.1	2.4	0.3	196	8.3	4.1
S07626	2	HUN-10	1	O	-3.05	10	4.6	19	0.0	1.2	0.3	315	15.6	1.6
S07627	2	HUNM-10	1	O	-1.52	10	4.6	25	0.0	4.0	0.5	425	19.4	1.1
S07628	2	HUC-10	1	O	0	10	4.5	22	0.0	1.5	0.3	348	15.3	1.3
S07629	2	HUSM-10	1	O	1.52	10	4.6	12	0.0	1.4	0.2	256	13.2	1.6
S07630	2	HUS-10	1	O	3.05	10	4.7	19	0.0	1.7	0.3	329	16.3	1.7
S07631	2	HUN-20	1	O	-3.05	20	4.6	17	0.0	1.2	0.1	172	7.5	2.2
S07632	2	HUNM-20	1	O	-1.52	20	4.6	32	0.0	1.7	0.2	251	15.3	1.7
S07633	2	HUC-20	1	O	0	20	4.6	17	0.0	0.3	0.2	215	8.7	2.0
S07634	2	HUSM-20	1	O	1.52	20	4.7	18	0.0	1.2	0.1	211	8.9	2.1
S07635	2	HUS-20	1	O	3.05	20	4.7	15	0.0	0.6	0.1	177	7.5	2.7
S07636	2	HUN-30	1	O	-3.05	30	4.8	10	0.0	0.7	0.0	117	5.4	3.4
S07637	2	HUNM-30	1	O	-1.52	30	4.7	24	0.7	1.3	0.2	168	9.3	2.4
S07638	2	HUC-30	1	O	0	30	4.7	13	0.0	0.5	0.1	139	5.9	2.8
S07639	2	HUSM-30	1	O	1.52	30	4.5	24	0.0	0.7	0.0	102	3.5	1.3
S07640	2	HUS-30	1	O	3.05	30	4.7	19	0.0	1.4	0.2	118	5.2	3.7
S07666	2	CUN-10	2	O	-3.05	10	4.5	14	0.6	2.6	0.8	433	20.8	2.7
S07667	2	CUNM-10	2	O	-1.52	10	4.5	15	0.4	1.1	0.7	392	18.1	2.5
S07668	2	CUC-10	2	O	0	10	4.6	11	0.5	1.5	0.9	316	19.6	3.5
S07669	2	CUSM-10	2	O	1.52	10	4.5	9	0.5	1.2	0.6	295	15.2	3.0
S07670	2	CUS-10	2	O	3.05	10	4.5	7	0.5	1.2	0.8	214	12.6	3.7
S07671	2	CUN-20	2	O	-3.05	20	4.6	9	0.3	0.8	0.7	151	8.3	3.3
S07672	2	CUNM-20	2	O	-1.52	20	4.5	7	0.5	1.4	0.6	161	10.2	3.6
S07673	2	CUC-20	2	O	0	20	4.6	15	0.4	0.5	0.5	145	8.7	5.2
S07674	2	CUSM-20	2	O	1.52	20	4.6	7	0.3	0.4	0.7	140	8.4	4.9

S07675	2	CUS-20	2	O	3.05	20	4.7	5	0.4	0.8	0.7	131	7.0	3.9
S07676	2	CUN-30	2	O	-3.05	30	4.5	10	0.3	0.5	0.8	70	3.8	2.8
S07677	2	CUNM-30	2	O	-1.52	30	4.7	5	0.4	0.9	0.9	112	6.1	4.5
S07678	2	CUC-30	2	O	0	30	4.9	14	0.7	1.4	0.5	110	5.6	3.2
S07679	2	CUSM-30	2	O	1.52	30	4.7	9	0.5	1.3	1.3	84	5.0	6.7
S07680	2	CUS-30	2	O	3.05	30	4.5	6	0.3	1.4	1.0	116	6.0	3.8
S07366	3	HFN-10	1	F	-3.05	10	4.6	6	0.6	1.2	0.2	146	3.7	3.1
S07367	3	HFNM-10	1	F	-1.52	10	4.7	8	0.4	1.3	0.1	136	5.8	1.9
S07368	3	HFC-10	1	F	0	10	4.8	28	0.7	4.1	10.9	274	15.3	2.9
S07369	3	HFSM-10	1	F	1.52	10	4.7	11	0.5	2.1	0.3	204	13.1	2.5
S07370	3	HFS-10	1	F	3.05	10	4.9	10	0.6	1.4	0.3	243	13.1	2.1
S07371	3	HFN-20	1	F	-3.05	20	5.1	5	0.5	3.6	0.8	61	0.0	2.2
S07372	3	HFNM-20	1	F	-1.52	20	4.9	5	0.5	0.7	0.3	51	1.9	2.7
S07373	3	HFC-20	1	F	0	20	4.5	22	4.1	1.9	0.8	141	7.4	10.1
S07374	3	HFSM-20	1	F	1.52	20	4.7	5	0.7	2.0	0.1	123	2.7	3.9
S07375	3	HFS-20	1	F	3.05	20	4.7	6	0.6	2.5	0.3	68	1.0	4.7
S07376	3	HFN-30	1	F	-3.05	30	4.8	5	0.4	0.8	0.0	34	0.9	2.4
S07377	3	HFNM-30	1	F	-1.52	30	4.8	6	0.7	0.7	0.0	57	1.8	2.3
S07378	3	HFC-30	1	F	0	30	4.4	43	17.0	5.7	0.0	32	0.0	0.5
S07379	3	HFSM-30	1	F	1.52	30	4.7	5	0.7	0.8	0.3	63	2.5	6.5
S07380	3	HFS-30	1	F	3.05	30	4.6	14	0.5	1.9	0.1	62	0.8	3.0
S07853	3	CFN-10	2	F	-3.05	10	4.8	9	0.0	0.3	0.8	194	15.8	3.0
S07854	3	CFNM-10	2	F	-1.52	10	4.8	6	0.0	0.2	1.2	175	10.9	2.4
S07855	3	CFC-10	2	F	0	10	4.8	6	0.0	0.2	0.9	138	12.1	3.0
S07856	3	CFSM-10	2	F	1.52	10	5.0	8	0.7	0.4	0.0	180	13.6	3.9
S07857	3	CFS-10	2	F	3.05	10	4.3	5	0.3	1.0	0.5	89	8.2	6.6
S07858	3	CFN-20	2	F	-3.05	20	4.7	6	0.4	6.7	0.3	152	0.2	4.8
S07859	3	CFNM-20	2	F	-1.52	20	4.7	7	0.0	0.0	0.8	150	3.7	2.2
S07860	3	CFC-20	2	F	0	20	4.7	2	0.1	0.0	0.8	51	4.0	3.7
S07861	3	CFSM-20	2	F	1.52	20	4.8	5	0.5	0.0	0.4	105	7.8	6.5
S07862	3	CFS-20	2	F	3.05	20	4.9	6	0.1	0.0	0.1	89	5.1	3.7

S07863	3	CFN-30	2	F	-3.05	30	4.7	4	0.0	0.0	1.0	55	2.8	3.8
S07864	3	CFNM-30	2	F	-1.52	30	5.0	5	0.0	0.0	0.5	50	3.6	3.6
S07865	3	CFC-30	2	F	0	30	4.8	4	0.2	0.0	0.5	52	4.2	6.3
S07866	3	CFSM-30	2	F	1.52	30	4.6	7	0.0	0.0	0.7	37	3.0	4.1
S07867	3	CFS-30	2	F	3.05	30	4.9	5	0.1	0.0	0.4	42	3.7	4.6
S07386	3	HUN-10	1	O	-3.05	10	4.7	11	0.4	2.4	0.1	140	8.8	2.7
S07387	3	HUNM-10	1	O	-1.52	10	5.2	31	0.5	1.7	0.3	273	11.4	1.4
S07388	3	HUC-10	1	O	0	10	4.6	31	0.8	1.8	1.5	353	20.6	1.6
S07389	3	HUSM-10	1	O	1.52	10	5.0	17	0.9	1.1	1.2	294	12.3	1.4
S07390	3	HUS-10	1	O	3.05	10	4.9	8	0.6	1.8	0.1	172	8.4	1.8
S07391	3	HUN-20	1	O	-3.05	20	4.7	17	0.3	1.4	0.1	69	0.0	0.8
S07392	3	HUNM-20	1	O	-1.52	20	4.7	14	0.7	0.8	0.0	105	5.6	2.5
S07393	3	HUC-20	1	O	0	20	4.8	19	0.6	1.8	0.1	119	6.7	3.0
S07394	3	HUSM-20	1	O	1.52	20	4.9	12	0.6	1.0	0.1	168	4.8	2.0
S07395	3	HUS-20	1	O	3.05	20	4.7	7	0.6	3.0	0.1	74	0.9	2.7
S07396	3	HUN-30	1	O	-3.05	30	4.7	20	1.2	2.2	0.0	57	0.0	0.3
S07397	3	HUNM-30	1	O	-1.52	30	4.8	21	0.5	0.6	0.1	91	3.1	0.7
S07398	3	HUC-30	1	O	0	30	4.8	31	0.4	1.0	0.0	56	0.0	0.8
S07399	3	HUSM-30	1	O	1.52	30	4.8	10	1.2	2.0	0.3	151	3.4	3.0
S07400	3	HUS-30	1	O	3.05	30	4.6	11	0.8	1.6	1.2	160	6.5	2.4
S07426	3	CUN-10	2	O	-3.05	10	4.7	7	0.5	0.0	0.3	157	10.1	3.1
S07427	3	CUNM-10	2	O	-1.52	10	4.7	4	0.3	0.0	0.2	109	6.2	3.5
S07428	3	CUC-10	2	O	0	10	4.6	8	0.3	2.8	1.0	180	8.5	1.9
S07429	3	CUSM-10	2	O	1.52	10	5.8	6	0.5	1.6	1.4	176	8.9	2.1
S07430	3	CUS-10	2	O	3.05	10	4.6	8	0.3	1.0	0.4	234	11.9	1.9
S07431	3	CUN-20	2	O	-3.05	20	4.9	2	0.3	0.0	0.1	50	2.6	1.9
S07432	3	CUNM-20	2	O	-1.52	20	4.8	2	0.1	0.0	0.2	392	51.0	0.5
S07433	3	CUC-20	2	O	0	20	5.1	3	0.3	0.0	0.4	88	4.2	3.1
S07434	3	CUSM-20	2	O	1.52	20	5.0	4	0.3	0.0	0.1	99	6.6	3.0
S07435	3	CUS-20	2	O	3.05	20	4.9	4	0.3	0.0	0.2	103	8.1	2.8
S07436	3	CUN-30	2	O	-3.05	30	4.8	4	0.1	0.0	0.0	35	1.8	0.4

S07437	3	CUNM-30	2	O	-1.52	30	4.7	3	0.3	0.0	0.3	61	3.3	4.2
S07438	3	CUC-30	2	O	0	30	4.8	4	0.2	0.0	0.1	44	1.3	2.1
S07439	3	CUSM-30	2	O	1.52	30	5.2	4	0.3	0.0	0.3	73	3.8	3.0
S07440	3	CUS-30	2	O	3.05	30	4.8	6	0.2	0.0	0.1	55	2.8	1.5
S07526	4	HFN-10	1	F	-3.05	10	4.6	10	24.5	6.3	0.5	164	4.9	4.7
S07527	4	HFNM-10	1	F	-1.52	10	4.8	49	34.0	11.0	1.8	226	8.9	3.2
S07528	4	HFC-10	1	F	0.00	10	4.6	26	44.1	2.8	5.4	190	11.3	4.0
S07529	4	HFSM-10	1	F	1.52	10	4.9	15	57.0	3.3	0.4	230	12.5	3.2
S07530	4	HFS-10	1	F	3.05	10	4.7	10	63.8	4.2	0.4	167	4.5	4.0
S07531	4	HFN-20	1	F	-3.05	20	4.3	5	73.8	4.6	0.0	75	1.3	5.1
S07532	4	HFNM-20	1	F	-1.52	20	4.2	76	84.4	31.4	0.0	71	0.0	3.7
S07533	4	HFC-20	1	F	0.00	20	4.6	41	95.5	15.4	0.7	136	2.6	11.5
S07534	4	HFSM-20	1	F	1.52	20	4.9	7	103.7	4.9	0.2	86	0.0	4.5
S07535	4	HFS-20	1	F	3.05	20	4.1	5	114.7	1.6	0.0	111	2.2	5.7
S07536	4	HFN-30	1	F	-3.05	30	5.2	7	125.2	4.1	0.2	51	0.0	7.9
S07537	4	HFNM-30	1	F	-1.52	30	4.7	88	136.3	24.8	0.5	48	0.0	3.0
S07538	4	HFC-30	1	F	0.00	30	4.4	63	141.4	10.1	0.0	44	0.0	2.2
S07539	4	HFSM-30	1	F	1.52	30	4.8	7	153.2	1.3	0.0	51	0.0	3.8
S07540	4	HFS-30	1	F	3.05	30	4.5	7	167.9	1.0	0.0	70	0.0	4.9
S07546	4	HUN-10	1	O	-3.05	10	4.5	11	174.4	1.0	0.0	204	5.5	2.7
S07547	4	HUNM-10	1	O	-1.52	10	4.1	24	186.0	5.1	1.7	335	13.8	2.5
S07548	4	HUC-10	1	O	0.00	10	4.5	28	195.9	3.2	13.4	307	17.6	2.7
S07549	4	HUSM-10	1	O	1.52	10	4.5	29	206.2	3.0	5.3	279	15.1	2.8
S07550	4	HUS-10	1	O	3.05	10	4.6	14	214.9	2.5	0.0	245	7.7	2.0
S07551	4	HUN-20	1	O	-3.05	20	4.9	4	229.4	2.5	0.0	105	2.0	2.8
S07552	4	HUNM-20	1	O	-1.52	20	4.5	17	238.8	1.0	0.0	112	2.0	2.8
S07553	4	HUC-20	1	O	0.00	20	4.6	24	240.7	1.6	0.0	116	3.0	2.7
S07554	4	HUSM-20	1	O	1.52	20	4.4	40	258.5	1.9	0.0	114	2.4	2.7
S07555	4	HUS-20	1	O	3.05	20	4.7	5	262.7	1.8	0.0	82	0.0	3.9
S07556	4	HUN-30	1	O	-3.05	30	3.8	7	270.6	1.7	0.0	83	0.0	5.5
S07557	4	HUNM-30	1	O	-1.52	30	4.6	21	291.2	0.8	0.0	84	0.7	2.0

S07558	4	HUC-30	1	O	0.00	30	4.3	49	289.1	2.3	0.0	94	1.9	2.8
S07559	4	HUSM-30	1	O	1.52	30	4.2	61	300.5	1.2	0.0	52	0.0	2.9
S07560	4	HUS-30	1	O	3.05	30	4.6	9	313.1	1.5	0.2	104	0.9	3.5
S07838	5	NC N-10	2	O	-3.05	10	5.1	3	24.8	0.0	0.0	84	5.7	4.4
S07839	5	NC NM-10	2	O	-1.52	10	5.5	10	26.8	0.7	0.0	61	5.5	8.7
S07840	5	NC C-10	2	O	0.00	10	4.8	4	0.4	0.0	0.4	96	5.6	6.7
S07841	5	NC SM-10	2	O	1.52	10	5.1	4	0.2	0.8	0.0	84	5.7	5.2
S07842	5	NC S-10	2	O	3.05	10	5.2	2	0.5	0.3	0.0	77	5.0	8.2
S07843	5	NC N-20	2	O	-3.05	20	5.0	0	0.7	0.0	0.4	50	2.9	12.7
S07844	5	NC NM-20	2	O	-1.52	20	4.9	2	0.5	0.2	0.8	44	2.7	14.1
S07845	5	NC C-20	2	O	0.00	20	5.2	1	1.1	1.2	0.0	53	2.1	14.9
S07846	5	NC SM-20	2	O	1.52	20	5.6	1	0.3	0.0	0.0	43	3.6	11.6
S07847	5	NC S-20	2	O	3.05	20	5.0	8	0.5	0.0	0.0	70	6.9	5.1
S07848	5	NC N-30	2	O	-3.05	30	5.7	2	0.2	0.0	0.0	38	3.0	11.0
S07849	5	NC NM-30	2	O	-1.52	30	5.4	3	0.4	0.2	0.0	49	3.0	8.3
S07850	5	NC C-30	2	O	0.00	30	5.6	3	0.6	0.0	0.0	57	3.4	10.7
S07851	5	NC SM-30	2	O	1.52	30	5.2	2	0.4	0.0	0.1	36	2.0	11.1
S07852	5	NC S-30	2	O	3.05	30	5.2	2	0.5	0.2	0.0	46	3.9	10.8
S07686	5	HFN-10	1	F	-3.05	10	4.9	8	1.4	2.1	0.4	138	4.1	12.8
S07687	5	HFNM-10	1	F	-1.52	10	4.8	43	20.7	6.2	2.0	172	9.3	10.2
S07688	5	HFC-10	1	F	0.00	10	4.7	137	95.0	46.1	13.3	141	3.8	6.7
S07689	5	HFSM-10	1	F	1.52	10	5.0	22	1.5	2.8	4.6	333	17.6	6.3
S07690	5	HFS-10	1	F	3.05	10	5.2	17	0.7	2.0	0.2	281	10.4	4.6
S07691	5	HFN-20	1	F	-3.05	20	5.0	5	1.6	3.8	0.2	68	0.0	14.1
S07692	5	HFNM-20	1	F	-1.52	20	4.7	55	26.4	18.2	0.1	39	0.6	4.2
S07693	5	HFC-20	1	F	0.00	20	5.0	100	64.6	61.1	4.9	234	7.6	14.8
S07694	5	HFSM-20	1	F	1.52	20	5.0	15	6.3	10.5	0.6	209	6.8	7.5
S07695	5	HFS-20	1	F	3.05	20	5.0	7	6.3	9.6	0.9	174	4.2	14.6

S07696	5	HFN-30	1	F	-3.05	30	4.9	5	1.4	1.9	0.3	48	0.5	29.0
S07697	5	HFNM-30	1	F	-1.52	30	4.5	65	49.2	18.3	0.0	36	0.0	0.8
S07698	5	HFC-30	1	F	0.00	30	5.2	94	64.3	67.3	2.6	188	0.3	18.0
S07699	5	HFSM-30	1	F	1.52	30	4.9	12	3.8	3.7	0.1	74	1.9	8.9
S07700	5	HFS-30	1	F	3.05	30	5.3	11	1.2	1.2	0.4	118	2.0	16.4
S07706	5	HUN-10	1	O	-3.05	10	5.2	19	0.5	2.2	0.5	134	8.6	5.5
S07707	5	HUNM-10	1	O	-1.52	10	4.9	40	7.5	9.7	13.3	272	15.9	3.6
S07708	5	HUC-10	1	O	0.00	10	4.8	31	5.5	3.1	26.6	250	17.8	5.9
S07709	5	HUSM-10	1	O	1.52	10	5.1	26	3.9	8.6	7.3	181	6.5	5.5
S07710	5	HUS-10	1	O	3.05	10	5.3	7	0.7	1.2	0.3	160	6.2	5.6
S07711	5	HUN-20	1	O	-3.05	20	5.9	4	0.9	8.0	0.5	120	0.0	6.5
S07712	5	HUNM-20	1	O	-1.52	20	4.8	20	0.6	1.0	0.9	166	7.4	5.9
S07713	5	HUC-20	1	O	0.00	20	4.7	23	6.0	3.3	1.4	127	6.0	9.2
S07714	5	HUSM-20	1	O	1.52	20	4.7	28	0.9	1.4	0.3	87	5.0	4.3
S07715	5	HUS-20	1	O	3.05	20	5.0	2	1.0	1.2	0.4	88	1.7	15.6
S07716	5	HUN-30	1	O	-3.05	30	5.0	1	0.6	0.9	0.3	103	2.1	8.5
S07717	5	HUNM-30	1	O	-1.52	30	5.2	15	1.1	2.9	1.0	139	3.6	6.8
S07718	5	HUC-30	1	O	0.00	30	4.8	50	31.8	18.6	0.1	48	2.5	2.6
S07719	5	HUSM-30	1	O	1.52	30	4.9	20	0.9	0.9	1.6	74	3.5	9.4
S07720	5	HUS-30	1	O	3.05	30	5.3	5	1.1	2.2	0.8	116	5.4	7.4
S07726	5	CFN-10	2	F	-3.05	10	5.2	8	0.9	2.1	0.4	198	11.5	6.2
S07727	5	CFNM-10	2	F	-1.52	10	5.5	5	1.1	1.4	0.3	202	13.2	6.1
S07728	5	CFC-10	2	F	0.00	10	5.2	7	0.8	5.2	0.3	233	12.2	4.9
S07729	5	CFSM-10	2	F	1.52	10	5.2	9	0.8	4.1	0.3	191	9.3	5.4
S07730	5	CFS-10	2	F	3.05	10	5.3	7	0.6	11.1	0.3	182	8.7	4.0
S07731	5	CFN-20	2	F	-3.05	20	5.4	6	0.7	1.5	0.2	186	6.9	3.4
S07732	5	CFNM-20	2	F	-1.52	20	5.8	3	0.9	3.1	0.2	88	1.8	11.2
S07733	5	CFC-20	2	F	0.00	20	5.4	3	1.6	1.8	0.4	100	4.4	17.7
S07734	5	CFSM-20	2	F	1.52	20	5.4	4	0.8	1.9	0.2	131	7.7	8.1
S07735	5	CFS-20	2	F	3.05	20	5.3	5	0.8	1.0	0.2	137	6.3	6.4
S07736	5	CFN-30	2	F	-3.05	30	5.5	5	1.4	2.7	0.3	167	7.0	10.0

S07737	5	CFNM-30	2	F	-1.52	30	5.2	3	1.4	2.1	0.2	83	2.3	16.5
S07738	5	CFC-30	2	F	0.00	30	5.8	4	0.6	3.1	0.0	46	0.0	10.4
S07739	5	CFSM-30	2	F	1.52	30	5.2	2	1.0	4.6	0.2	80	0.0	12.9
S07740	5	CFS-30	2	F	3.05	30	5.0	2	0.8	1.5	0.1	84	3.1	9.7

APPENDIX B. Soil metal data derived from X-Ray Fluorescence used to confirm soil series at each site. Numbers for Figure 12 can be used to to assess treatment for each plot. HF=Fenced Hog, HO=Open Hog, CO=Open control and CF=Fenced Control.

Site	Figure 12	Series	K	Ti	Cr	Mn	Fe	Zn	Rb	Sr	Zr	Ba	Pb
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1HF	2	Longview1	4008	6109	46	316	7565	14.2	19.9	33.8	956	221	16.7
1HO	3	Longview1	4123	6878	63	530	12063	14.6	23.3	39.9	875	265	28.1
1CO	4	Longview1	3749	6215	53	345	10111	12.6	22	30.4	850	224	15.4
1HF	18	Longview1	3955	5756	41	541	7677	13.2	21.4	33.6	951	197	17.6
1HO	19	Longview1	4096	6206	55	334	14283	10	22.7	36.6	850	233	20
1CO	20	Longview1	3947	6302	52	492	8479	9.9	22.7	33.2	883	235	17.1
3HO	9	Mantachie3	6828	5299	83	2486	21545	41	43.7	43.2	553	364	20.2
3CO	11	Mantachie3	5690	4791	44	782	5887	14.3	21.5	24.9	940	197	11.7
3HO	25	Mantachie3	6843	4447	76	863	21926	29	39	32	613	293	13.9
3CO	27	Mantachie3	5852	4471	43	568	6123	27.9	23.1	26.3	849	205	14.8
2HF	5	Mathiston2	6202	4590	70	547	11728	32	43.1	49.9	633	297	16.3
2HO	6	Mathiston2	7392	4905	73	923	13700	43	55.7	63.3	573	379	14.9
2CO	7	Mathiston2	6769	5068	69	636	12677	28	41.5	49.6	712	293	20
2HF	21	Mathiston2	6617	4811	65	1029	12478	34	52	54.9	600	343	15.4
2HO	22	Mathiston2	6718	5163	69	1211	11674	38	49.1	60.1	647	339	16.7
2CO	23	Mathiston2	6341	4965	60	545	12230	22.1	43.2	45.4	642	292	16.4
3HF	8	Mathiston3	6532	5178	55	423	9504	24.4	33.9	39.2	714	273	21.5
3CF	10	Mathiston3	6162	4909	54	937	9467	30	33.2	35	623	235	15.2
3HF	24	Mathiston3	6875	5243	62	799	10350	27	39.6	40.2	735	286	18.8
3CF	26	Mathiston3	6290	4768	63	852	10887	22.4	32.4	35.9	539	254	12.7
4CO	1	Prentiss4	4757	4820	44	362	5267	14.2	20.9	28	857	184	16.4
4HF	12	Prentiss4	5001	4845	48	399	5788	11	23	30	833	207	16.2

4HO	13	Prentiss4	6304	5187	50	412	10276	20.8	35.2	41.8	715	276	17.6
4CO	17	Prentiss4	5326	5248	43	356	5502	14.9	24	28.3	939	207	11.2
4HF	28	Prentiss4	4953	4817	37	348	5010	9.7	21.7	27.1	987	204	10.5
4HO	29	Prentiss4	5718	5208	61	699	9497	19.1	33.7	41.4	727	274	17
5HF	14	Savannah5	6271	5682	62	192	14487	24.1	39.5	38.8	866	236	15.6
5HO	15	Savannah5	6939	4982	75	1988	15623	34	37.9	40	898	304	18.1
5CF	16	Savannah5	6796	4675	71	947	16231	27	44	38.8	719	297	20
5HF	30	Savannah5	5043	5561	54	436	12895	23.6	33.5	35	1068	239	22.6
5HO	31	Savannah5	6552	5498	63	989	16697	24.6	33.6	26.4	860	262	18.8
5CF	32	Savannah5	4694	3619	47	1365	8207	16.8	16.8	20.2	430	190	15.1

APPENDIX C. Permission to use figures (Pratt & Fonstad Email).

TEXAS A&M UNIVERSITY

Vanessa Limon <limonv12@tamu.edu>

Permission to use Figures from Livestock Mortality Paper

Pratt, Dyan <dyan.pratt@usask.ca> Mon, Mar 19, 2018 at 11:33 AM
To: Vanessa Limon <limonv12@tamu.edu>, "Fonstad, Terry" <terry.fonstad@usask.ca>

Hi Vanessa,

Glad to hear the work is continuing on! I am ok with you using the figures, and your poster looks great. I might suggest you update the reference to the Peer-reviewed article as follows (I attached it for your reference since it's not online yet):

Pratt, D.L. & T.A. Fonstad. (2018) Speciation and Geochemical Implications of Carcass Burial Leachate. Transactions of the ASABE. 61(2).

You may also want to update your reference list with our newest publications.

Pratt, D. L. and T. A. Fonstad (2017). Geochemical evolution and leachate transport beneath two carcass burial sites: A Field Investigation. Transactions of the ASABE. 60(6)

Pratt, D. L. and T. A. Fonstad (2017). Geochemical modeling of livestock mortality leachate transport through the subsurface. Biosystems Engineering. (162)

Pratt, D. L. (2017). Biogeochemical Implications of Animal Mortality Burial. Civil, Geological and Environmental Engineering. Saskatoon, SK, University of Saskatchewan. Ph.D. Thesis.

Best of luck with your work, we look forward to reading it!

Cheers,

Dyan

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